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STATE GEOLOGICAL SURVEY
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U. S. DEPT. OF THE INTERIOR
U. S. GEOLOGICAL SURVEY
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BULLETIN 16

THE RED IRON ORES

OF

EAST TENNESSEE

BY
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The Red Iron Ores of East Tennessee

BY

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INTRODUCTION.

General statement.—The attention of the iron makers of the United States has been turning toward the Southern iron ore fields to a considerable extent during the last decade, but more particularly since it has been proved possible successfully to make basic open hearth steel from Southern iron ore. In response to many inquiries for information concerning the various ore fields and the utilization of the ores, the State Geological Surveys of Alabama and Georgia have already issued special reports on these subjects and the United States Geological Survey has issued several reports, some of them covering interstate areas.

Scope of this report.—This bulletin on the Red Iron Ores of East Tennessee, written for publication by the State Geological Survey of Tennessee, is intended to describe the red iron ores of the northern part of what has, in a broad way, been termed the Chattanooga District. The material presented herewith will, it is expected, be combined later with descriptions of the ore beds extending southwest of Chattanooga, as far as Springville, Alabama, and southeast of Chattanooga as far as Rome, Georgia, and be published as a bulletin by the United States Geological Survey.

After the full work of the author had been completed an investigation of the iron ore deposits of the Tuckahoe District was made by Professors C. H. Gordon and R. P. Jarvis, of the University of Tennessee, and the results were published by the Tennessee Geological Survey in the Resources of Tennessee in December, 1912. Although the iron ore of the Tuckahoe District is largely limonite it is so closely allied in origin and geologic relations to certain red ore deposits of the State that it has been decided to include in this bulletin important extracts from the report by Gordon and Jarvis.

The general geology of East Tennessee has already been worked out by the U. S. Geological Survey, and is described, with geologic maps, in a series of geologic folios, the names of which are given on page 18. On account of the great expense that reproduction of these

geologic maps would entail, and since they are not wholly necessary to the interpretation of the relations of the ore beds, they have not been included in this bulletin. Topographic maps covering the areas under discussion have been given, however. These topographic maps are drawn on the scale of 1:125,000, or practically 2 miles to 1 inch. They

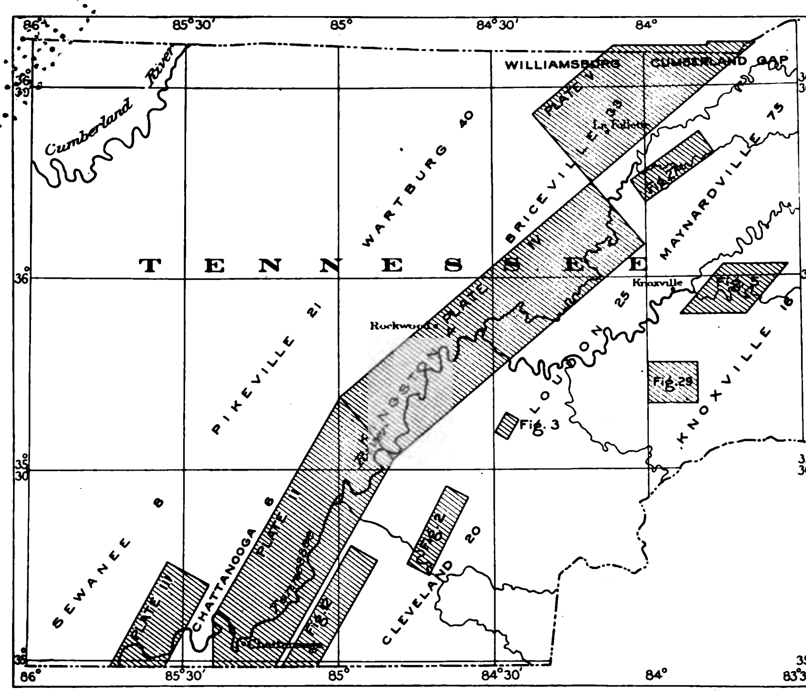

FIGURE 1.—Index to maps and folios.

are drawn on the same base as the old maps of the U. S. Geological Survey, and while in many places they are not correct as to details, they represent the latest maps available. These maps, Pls. II to V, and Figs. 2, 3, 5, 12, 27, and 29, indicate the surface features of the country, and the works of man such as cities and towns, railroads, wagon roads, mines, coke ovens, blast furnaces, etc. On these maps have been traced the approximate outcrops of the iron ore beds and the faults against which they terminate in places. An attempt has been made to differentiate between areas of ore beds that are probably workable and those that are probably not workable under present conditions, by means of a different symbol on the map. The basis for this division is more or less arbitrary, a thickness of 2 feet being considered as below the present minimum workable thickness underground, for ore beds of fair quality. On maps of such small scale as has been used in this bulletin it is obviously impossible to show with absolute accuracy the limits of the ore beds

thinner or thicker than 2 feet, and therefore for local details the reader is referred to the ore sections given in the text. The location of the various ore sections is shown on the maps by symbols numbered to correspond with the sections as outlined and illustrated graphically in the text.

Prospecting the ore beds:—Heretofore in describing the iron ores of an area the author has been obliged to depend entirely upon natural exposures of the ore beds or upon exposures made by mining operations, roads, tunnels, etc. The soft, shaly nature of much of the rock overlying the red ore causes the shale above a fresh ore prospect to "slump" down within a few months and practically to cover up an ore showing. The result is, therefore, that except where mining is actually in progress, there are very few exposures of ore beds, even though many fresh prospects may have been made within a year. The geologist who attempts to prepare a report on a bedded ore field must either accept much hearsay evidence concerning the thickness and character of the ore beds, or else he or a member of his party must see and measure every section on which the report is based. This latter plan was consistently carried out in the field work of the present investigation. In order that no very long gaps should occur between measured sections, prospecting the ore beds on the outcrops at points where actual measurements were of importance was undertaken. In many instances it was necessary only to clean out old prospects, but in others fresh openings were dug. Wherever practicable the bed was cut back to firm ore, in order to ascertain its true thickness. At many of these prospects samples of ore were taken for analysis by the U. S. Geological Survey.

Organization and assistance.—The field work on which this report is based was done in the autumn of 1911, although the author has drawn freely on notes made by him during visits to certain mines in 1906 and 1908. The greater part of the expense was borne jointly by the State Geological Survey of Tennessee and the United States Geological Survey. The Chattanooga Chamber of Commerce made a contribution which was used to partly defray the expenses of prospecting.

The work of prospecting was in charge of Mr. J. R. Ryan, a mining superintendent and contractor of Chattanooga. Mr. Ryan made the measurements of many of the sections described in this bulletin and in many other ways rendered valuable assistance. It is largely due to his thorough knowledge of the Chattanooga district, and to the generous and loyal spirit in which he served the State, that the field work on which this report is based was accomplished within the funds allotted for the purpose.

The city of Chattanooga lies within 4 miles of the southern boundary of the State, and since there are more important reserves of red iron ore

within 30 to 40 miles south of the city than within an equal distance northward, it was the desire of the Chattanooga Chamber of Commerce that part of the funds allotted for prospecting the ores should be used in Alabama and Georgia in order to demonstrate the value of the ores tributary to the city. The prospecting was accordingly done without reference to State boundaries. A general summary of the results of all this work is in preparation and will be published by the United States Geological Survey in the summer of 1913.

It was the wish of the author that this bulletin might be written during the winter following the field work, but its preparation has been unavoidably delayed by other duties in the service of the United States Geological Survey which have taken precedence. Little or no new development has taken place in the red iron ore areas during 1912, so that the data here presented with regard to the ore beds are believed to be practically up to date.

Previous geologic work.—Geologic work on the red iron ores of East Tennessee dates back for more than three-quarters of a century. As early as 1835 Dr. Gerard Troost[1] wrote with regard to his duties as State Geologist:

"My principal aim in these examinations was: * * * * * 4th. To ascertain the various deposits of iron ore, and the number and nature of the works for which they furnish the requisite ore; at the same time as it is of paramount importance that the Legislature should know of what benefit these invaluable works are to the State I have begun to collect facts, which, if the owners of the iron works will furnish me with the necessary data, will enable me to lay at a future session before your honorable body a statistical account of our iron establishments, from which it will appear how far they are able to furnish all the iron necessary for the consumption of the State, and what quantity remains for exportation into other States."

In his fourth report[2], Troost says:

"On the foot of the Lookout Mountain, and below the oolitic stratum characterized by pentremites * * * are some deposits of scaly red oxide of iron, similar to the ore which is worked by Messrs. Gordon and Kimbrow in Roane County, and which is found along the eastern base of the whole Cumberland mountain as far as the Cumberland gap; and the whole is superimposed by sandstone, similar to that of the Cumberland mountain, and consequently belongs to the coal measures."

The red iron ores are discussed further by Troost in his Fifth Report, in 1839, and in his Eighth Report, in 1845, but in the series of reports by Troost the subject is not given the prominence that has been accorded it by later investigators.

[1]Troost, G., Third Geological Report to the Twenty-first General Assembly of the State of Tennessee Oct., 1835, p. 3.

[2]Troost, G., Fourth Geological Report to the Twenty-second General Assembly of the State of Tennessee, made Oct., 1837, p. 33.

INTRODUCTION.

Professor Safford[1], writing in 1855, presents an outline of the iron ore fields of Tennessee and their geologic relations. The species of ore discussed are as follows:

(1) Brown iron ore, or limonite.
(2) Red iron ore, or hematite, including two varieties:
 (*a*) Hard solid ore or red hematite.
 (*b*) Stratified dyestone ore.
(3) Magnetic iron ore, or magnetite.

The iron ore regions are enumerated as follows:

(1) Eastern Region. Extends along the front of the Unaka Mountains.

(2) "Dyestone" Region. Skirts the eastern base of Cumberland and Walden's Ridge from Virginia to Georgia, and extends laterally 10 to 20 miles into the Valley of East Tennessee, and also includes Sequatchie and Elk Valleys.

(3) Cumberland Region. Coextensive with the coal region in the northern part of the State.

(4) Western Region. Western part of Middle Tennessee.

The portions of Safford's report for 1855 that are of most interest in the present connection are his notes on the "stratified dyestone" in the "Dyestone" Region, although interesting mention is also made of certain outlying deposits in the Eastern Region. This report contains a black and white geological map of Tennessee on a scale of 12 miles to 1 inch, on which the outcrops of the red iron ore as then known are indicated.

In 1869 Professor Safford issued a more comprehensive volume[1] devoted mianly to the geology of the State, in which but little is added to the discussion of the iron ore resources that was published in 1856. This report is illustrated by a colored geologic map on a scale of 12 miles to 1 inch, in which the general geology and distribution of the red iron ores are shown with greater accuracy and detail than in the former report, but there are certain points in which there is disagreement with later maps.

In 1881 Killebrew[2] published a report devoted especially to the iron and coal resources and their development in the State. This report takes up in detail the occurrence and development of the "Dyestone" ore in the five following "belts": (1) Eastern base of Cumberland Plateau; (2) The areas in the Great Valley in Whiteoak Mountain, and in Meigs, Roane, Anderson, Union, Claiborne, and Hancock counties; (3) in McMinn county; (4) in Sequatchie Valley; and (5) in Elk Fork Valley. The ore in McMinn County has since been determined to be of earlier age than the "Rockwood," as is noted in this bulletin. In addition to the

[1]Safford, James M., A Geological Reconnaissance of the State of Tennessee: Tennessee Geological Survey, 1856, pp. 31-57 (164 pp. in all).

[1]Safford, James M., Geology of Tennessee: Tennessee Geological Survey, 1869, 550 pp.

[2]Killebrew, J. B., Iron and Coal of Tennessee: Tennessee Commission of Agriculture and Mines, 1881, 220 pp.

notes on these areas certain ore beds in Knox County, between French Broad and Holston rivers are mentioned. This ore, which is also older than the "Rockwood" is described by Gordon and Jarvis in the present bulletin. The report by Killebrew shows, in a series of 5 plates on which the ore outcrops are printed in red, the distribution of the ore beds. This report is more detailed than either of Safford's, and in its general details as to distribution of iron ores accords with the work of the present writer, but contains at least one serious misinterpretation of the structure of the ore beds. For instance, in the Whiteoak Mountain area Killebrew shows a cross section carrying four beds of ore, drawn thus presumably to correspond with four parallel outcrops of ore at the surface. The four outcrops were, however, caused by the folding of strata containing a single bed of ore into overturned folds, the tops of which have been eroded, leaving apparently four beds of ore dipping in the same direction, (see Fig. 13).

From 1890 to 1902 Messrs. C. W. Hayes, Arthur Keith, M. R. Campbell, and other members of the U. S. Geological Survey were engaged in mapping the areal geology of East Tennessee, the results of which have been published in a series of geologic folios. The outcrop of the "Rockwood" iron ore beds shown on the maps in this bulletin practically corresponds to the mapping of these geologists, except in Sequatchie Valley. Mining developments in Tennessee and Alabama since the publication of these folios have shed so much light on the character of the deeply buried ore beds that a conception of this subject altogether different from that held a dozen years ago is now generally agreed upon.

In the spring of 1909 the writer published in Bulletin 380 of the U. S. Geological Survey[1] a preliminary estimate of tonnage of "Rockwood" iron ore in the Chattanooga Region of Tennessee, Georgia, and Alabama. In that paper brief descriptions of a number of ore-bearing areas in Tennessee were published, and these descriptions have been incorporated in the present bulletin. With regard to the estimates given in Bulletin 380 it may be said that further work has not demonstrated that any important changes should be made in the statements concerning the average thickness and quality of the ore beds in the Tennessee portions of the area as determined in more limited studies in 1908, but that the total ore reserves of the State may safely be greatly increased by slightly extending the limits of workability of the ore in the direction of the dip, and also on account of additional areas having been considered. For instance, an estimate of tonnage of iron ore in a large area between La Follette and Elk Valley has been added in this bulletin.

[1]Burchard, Ernest F., Tonnage estimates of Clinton iron ore in the Chattanooga Region of Tennessee Georgia, and Alabama. Bull. U. S. Geol. Survey No. 380, 1909, pp. 169–187.

With regard to estimates of available reserves of bedded iron ore, in general, there is always opportunity for great differences of opinion unless the estimates are based upon data so nearly complete that there is little room for the exercise of judgment. Unless the field is a small one and thoroughly prospected, there are several uncertain factors, prominent among which are: (a) distance in the direction of dip to which an ore bed may extend with unchanged thickness; (b) distance in the direction of dip to which an ore bed of known quality and thickness may be mined under present conditions. If these factors are not known more or less arbitrary ones must be chosen. Although it is generally admitted that an exaggerated estimate of the resources of a region may in the end do more harm than a safely conservative one, it is a well-known fact that conservative estimates are generally more freely and vigorously criticised than those loosely made and absurdly exaggerated. Recent estimates of iron ore tonnage in Southern fields that have been the subject of criticism might be doubled, or even trebled by sufficiently extending the postulated workable limits of the beds, but this would be hazardous, inasmuch as such increases would necessarily be based mainly on conjecture.

Acknowledgments.—In the study of the iron ores described in this bulletin much assistance was rendered the writer by officers of the iron mining and manufacturing companies of the district, by many individual property owners, by the Chattanooga Chamber of Commerce, and by members of the State Geological Survey. The writer desires particularly to acknowledge the courtesies of Messrs. H. S. and M. Chamberlain, L. S. Colyer, O. F. Janes, G. R. Lynch, J. P. Winn, and E. M. Jones, of Chattanooga; Polk Tarwater, of Rockwood; W. D. Gilman, of Sweetwater; Dr. Geo. H. Ashley, former State Geologist of Tennessee, Professors R. P. Jarvis and C. H. Gordon, of Knoxville, and Dr. E. O. Ulrich, of Washington, D. C. The latter gentleman has contributed the detailed sections of the "Rockwood" formation as published in this text.

GEOGRAPHY.

The area in Tennessee in which the red iron ores are found, with the exception of a small deposit north of Nashville, comprises those portions of East Tennessee known as the Cumberland Plateau and the Great Valley. The Cumberland Plateau is a table land that has been sharply cut by many branching streams, so that there remain only a few detached areas with flat tops reaching the highest level. Slightly lower than the highest upland there are also broad, flat areas which have a common level, and below this the deep stream valleys are cut. The general altitude of the highest upland ranges from about 1,800 feet above sea-level near Chattanooga to about 3,000 feet near Cumberland Gap. The Great Valley lies to the southeast of the Cumberland Plateau, and is separated from it by a comparatively steep bluff or escarpment. The Great Valley, as its name implies, is relatively lower than the Cumberland Plateau. It lies between the Cumberland Plateau on the northwest and the Great Smoky and Unaka mountains on the southeast. Its mean altitude above sea-level ranges from about 700 feet near Chattanooga to about 1,500 feet near the northern State line. The main streams cut lower than these levels, and many ridges within the valley rise to higher altitudes Except near the escarpment the rocks in the Cumberland Plateau lie nearly horizontal but the valley rocks are nearly everywhere tilted steeply so that the edges of the more resistant strata form the valley ridges. The plateau and valley together extend northeast-southwest across the State from Chattanooga to Cumberland Gap, a distance of 220 miles, and have a combined width varying between 60 and 80 miles. Although the iron ore underlies the eastern portion of the Cumberland Plateau, including Walden Ridge, these beds are accessible only where they outcrop near the base of the escarpment and in the deeper intermountain valleys such as Elk and Sequatchie valleys. It is therefore essential only to consider in this bulletin the general physical and commercial aspects of the Great Valley and of the minor valleys just mentioned.

The Great Valley has resulted from erosion by Tennessee River and its tributaries, the principal ones of which are the Hiwassee, the Little Tennessee, Clinch, and Powell Rivers. The general slope is from southeast to northwest, from the Appalachian Mountains toward the Cumberland escarpment and the position of Powell, Clinch, and Tennessee rivers but a few miles from the base of the escarpment suggests that erosion has progressed mainly westward. Southeast of the rivers the Great Valley is diversified by many ridges trending in a northeast-south-

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west direction, whose positions, characteristics, and trend are dependent on certain folds of the strata which will be described later. West of the rivers, near and parallel to the base of the Cumberland escarpment, is a broken line of foothills. These foothill ridges rise generally 200 to 500 feet above the rivers, and the valley ridges east of the rivers lie from from 400 to 700 feet above the level of the same streams. The surface of the Great Valley therefore is relatively hilly, except along the flood-plains of the streams. Three railway lines—the Cincinnati, New Orleans, and Texas Pacific; the Louisville and Nashville; and the Southern—traverse the State from northeast to southwest within the Great Valley. Branch lines extend to several important places not reached by the main lines. Tennessee River is also a highway of commerce and carries an important tonnage of iron ore between mines and furnaces. With the improvement of navigation that will follow the damming of the river at Hale's bar it may be expected that considerably more coal and ore will soon be brought to Chattanooga by water than is now handled in this way.

The two large cities in East Tennessee which are directly interested in the iron industry are Chattanooga and Knoxville, while Dayton, La Follette, and Rockwood are smaller cities where coke and pig iron are manufactured.

GEOLOGY.

STRATIGRAPHY.

General Statement.

Only the ore-bearing formations and the rocks immediately associated with them will be discussed here: The formations exposed in the Great Valley range in age from Lower Cambrian to Mississippian ("Lower Carboniferous") and in the Cumberland plateau they extend as high as Pennsylvanian ("Coal Measures"). The area is so large and so many formations of limited extent have been recognized locally, that no single generalized section would be representative of the rocks exposed in East Tennessee. The U. S. Geological Survey has issued topographic maps of a large part of the region, and has mapped the geology over most of the area covered by the topographic maps. Where geologic studies have been made the results have been embodied in a series of geologic folios, a list of which, with the principal minerals of economic value mentioned in the folios, is given in the following outline.

East Tennessee folios of the Geologic Atlas of the United States.

No.	Name of folio.	State.	Area in sq. m.	Author.	Mineral products[1] described as occurring in area of folio.
*2	Ringgold.........	Ga.-Tenn.....	980	Hayes, C. W........	*Coal, iron,* manganese, lime, clays, stone, road materials.
*4	Kingston.........	Tenn.........	969	Hayes, C. W........	*Coal, iron,* lime, stone, road materials, clay.
*6	Chattanooga......	Tenn.........	975	Hayes, C. W........	*Coal, iron,* lime, stone, road materials, clay.
*8	Sewanee..........	Tenn.........	975	Hayes, C. W........	*Coal, iron,* lime, stone, road materials, clay.
*16	Knoxville.........	Tenn.-N. C...	969	Keith, Arthur.......	*Marble,* slate, stone, gold, lime, cement, clay, water power.
*19	Stevenson........	Ga.-Ala.-Tenn.	980	Hayes, C. W........	*Coal, iron,* lime, stone, road materials, clay.
20	Cleveland........	Tenn.........	975	Hayes, C. W........	*Iron,* lead, lime, stone, clay.
21	Pikeville.........	Tenn.........	969	Hayes, C. W........	*Coal,* iron, stone, clay.
25	Loudon..........	Tenn.........	969	Keith, Arthur.......	*Coal,* marble, lime, stone, clay, iron, slate, water power.
33	Briceville.........	Tenn.........	963	Keith, Arthur.......	*Coal, iron,* lead, marble, lime, stone, clay.
75	Maynardville.....	Tenn.........	963	Keith, Arthur.......	*Marble,* coal, stone, lead, zinc, lime, road materials, clay, water power.

[1]Products of greatest importance are printed in *italic.*

Copies of these folios, except those marked *, may be purchased from the Director of the U. S. Geological Survey, Washington, D. C., for 25 cents each, and all topographic maps for 10 cents each.

Geologic Sections.

No single geologic section can be constructed that will adequately represent the sequence of formations for all parts of the East Tennessee red iron ore-bearing area. There are such wide differences in character and thickness of single formations as represented in the Great Valley and on the border of the Cumberland escarpment, and also such differences in the range of formations present in these two strips of country, that in most of the folios of the United States Geological Survey it was necessary to give two columnar sections—one representative of the rocks in the northwest and the other of the rocks in the southeast portion of each quadrangle. A few examples will serve to illustrate these differences In the valley areas the thickness of most of the pre-Carboniferous formations is much greater than in the plateau area. The "Rockwood" formation, for instance, as defined in the geologic folios, thins westward from 700 to 1,000 feet in Whiteoak Mountain and other ridges within the Great Valley to less than 200 feet along the Sequatchie. In the Valley areas the oldest formations exposed are much older than those of the Cumberland escarpment area, but the upper formations along the escarpment extend much higher in the stratigraphic scale than do those of the valley areas. Moreover, in the Valley areas certain thin formations that do not appear farther west, are interstratified with those of the Ordovician and Silurian systems. From southwest to northeast there are also changes in the stratigraphy, but not so abrupt as those from southeast to northwest. These changes are sufficiently noticeable, however, to require different columnar sections for each quadrangle. For example, certain Mississippian formations are recognized in the vicinity of Chattanooga that have no exact equivalents in the neighborhood of La Follette, and *vice versa.*

For the purpose of illustrating these general differences in stratigraphy and also the relative position of the "Rockwood" and other bedded iron ores in the geologic section, there are given below seven columnar sections as published with slight modification of the classification, by the United States Geological Survey in its Chattanooga, Kingston, Loudon, Briceville, and Maynardville geologic folios. These columnar sections exhibit the sequence, character, and thickness of the formations, both in the Valley areas and along the Cumberland escarpment, and also indicate the character of the topography and soils most typically developed on the surfaces of the various rocks. The rocks are classified systematically and are given appropriate letter symbols that correspond with those accompanying the structure sections, Figs. 4, 10, 13, 20, 22, 25, and 26.

Generalized section of Chattanooga quadrangle west of Tennessee River and south of Chickamauga Creek.

Period.	Formation Name.	Formation Symbols.	Thickness Ft.	Character of Rocks.	Character of Topography and Soils.
Carboniferous.	Walden sandstone.....	Cw	1200	Coarse sandstone and sandy shale with beds of coal and fire clay.	Flat topped, plateau-like mountains. Gray, yellow or red sandy loam.
	Lookout sandstone....	Cl	400–500	Conglomerate. Sandstone and sandy shale with beds of coal.	Cliffs; abrupt plateau escarpments. Scanty soil, rocky and sandy.
	Bangor limestone......	Cb	800–850	Shaly limestone. Massive, blue crinoidal limestone. Shaly limestone.	Steep mountain slopes and valleys. Black clay soil with more or less sand from rocks above. Narrow valleys. Red clay soil with sand and chert from adjacent slopes.
	Fort Payne chert......	Cp	60–150	Heavy bedded chert.	Sharp narrow ridges parallel to plateau escarpments. Sandy clay soil with abundant fragments of chert.
Dev.	Chattanooga shale.....	Dc	10–25	Carbonaceous shale.	
Sil.	"Rockwood" formation.	Sr	200–320	Greenish clay shale with beds of fossil iron ore.	
Ordovician.	Chickamauga limestone	Oc	1050–1300	Blue flaggy limestone.	Level valleys; shallow residual deposits of red or blue clay. Scanty blue clay soil where the limestone is nearly horizontal, and deeper red clay where they are steeply inclined.
Cambrian and Ordovician.	Knox dolomite........	€Ok	3300–2500	Magnesian limestone; white, gray, or light blue; generally granular and massively bedded; containing nodules and layers of chert.	Low ridges and irregular rounded hills; deep residual deposits of red clay and chert. Red clay soil with a few fragments of chert, grading into white or gray soil, composed almost entirely of chert.

Generalized section of Chattanooga quadrangle east of Tennessee River and south of Chickamauga Creek.

Period.	Formation Name.	Formation Symbols.	Thickness Ft.	Character of Rocks.	Character of Topography and Soils.
Carboniferous.	Lookout sandstone....	Cl	75+	Sandstone and shale.	Level top of Grindstone Mountain. Steep mountain slopes.
	Bangor limestone......	Cb	450–530	Massive, blue, crinoidal limestone.	Red clay soil with more or less sand from rocks above.
	Floyd shale...........	Cf	600–660	Carbonaceous sha'e with beds of blue crinoidal limestone.	Valleys with low rounded hills. Sandy clay soil.
	Fort Payne chert......	Cp	50–75	Calcareous sandstone and beds of chert.	Knobs parallel with Rockwood ridges; sandy soil with fragments of chert.
Dev.	Chattanooga shale.....	Dc	15–20	Carbonaceous shale.	
Silurian.	"Rockwood" formation.	Sr	950–1000	Greenish sandy shale with beds of red fossil iron ore. Brown and purple sandstone and sandy shale.	Prominent ridges with uniform elevation and slope. Rocky, sandy soil.
Ordovician.	Chickamauga limestone	Oc	2000–2200	Earthy limestone; mottled, purple and gray. Blue flaggy limestone.	Level valleys; shallow residual deposits of red or blue clay. Scanty blue clay soil where the limestone beds have low dips and deeper red clay where they are steeply inclined.
Ordovician. / Cambrian.	Knox dolomite........	€Ok	3300–3500	Magnesian limestone; white, gray or light blue; generally granular and massively bedded; containing nodules and layers of chert.	Low ridges and irregular rounded hills; deep residual deposits of red clay and chert. Red clay soil with a few fragments of chert, grading into white or gray soil, composed almost entirely of chert.
Cambrian.	Conasauga shale......	€c	1500–1700	Blue seamy limestone interbedded with clay shale. Olive green or brown clay shale. Thin beds of blue limestone, generally oolitic, interbedded with clay shale.	Level or rolling valleys. Stiff yellow or bluish gray clay soil.
	Rome formation.......	€r	3000–3500	Greenish or brown shale with thin siliceous layers. Purple, brown and white sandstone, interbedded with sandy shale.	Valleys with low ridges. Thin sandy clay soil. Comby ridges. Rocky, sandy soil.
		€rs	[500–800]	Sandstone.	
	Apison shale..........	€a	1000+	Sandy or clay shale in brightly colored alternating bands.	Narrow rolling valleys. Stiff clay soil.

Generalized section of Kingston quadrangle west of the Clinch and Tennessee rivers.

Period.	Formation Name.	Formation Symbols.	Thickness Ft.	Character of Rocks.	Character of Topography and Soils.
Carboniferous.	Walden sandstone.....	Cw	1300	Coarse sandstone and sandy shale with beds of coal and fire clay.	Flat topped, plateau-like mountains, intersected by narrow rocky gorges. Gray, yellow or red sandy loam.
	Lookout sandstone....	Cl	260–510	Conglomerate and massive sandstone; sandy shale with beds of coal and fire clay.	Cliffs; abrupt plateau escarpments. Scanty soil, rocky and sandy.
	Bangor limestone......	Cb	750–850	Shaly limestone. Massive, blue, crinoidal limestone. Sandy and shaly limestone.	Steep mountain slopes and coves. Black clay soil with more or less sand from rocks above. Narrow valleys. Red clay, with sand and chert from adjacent slopes.
	Fort Payne chert......	Cp	75–150	Cherty limestone.	Sharp narrow ridges parallel to plateau escarpments. Sandy clay soil with abundant fragments of chert.
Dev.	Chattanooga shale.....	Dc	15–30	Carbonaceous shale.	
Sil.	"Rockwood" formation.	Sr	165–650	Greenish clay shale with beds of fossil iron ore.	
Ordovician.	Chickamauga limestone	Oc	1300–1700	Blue flaggy limestone.	Level valleys: shallow residual deposits of red or blue clay. Scanty blue clay soil where the limestones are nearly horizontal and deeper red clay where they are steeply inclined.
Ordovician. / Cambrian.	Knox dolomite........	ЄOk	3300–3500	Magnesian limestone; white, gray, or light blue; generally granular and massively bedded; containing nodules and layers of chert.	Low ridges and irregular rounded hills; deep residual deposits of red clay and chert. Red clay soil with a few fragments of chert grading into white or gray soil, composed almost entirely of chert.
Cambrian.	Conasauga shale.......	Єc	300–500	Blue seamy limestone. Greenish clay shales. Thin beds of oolitic limestone.	
	Rome formation.......	Єr	2800–3400	Greenish or brown shales with thin siliceous layers.	Narrow level valleys. Stiff yellow or bluish gray clay soil.
		[Єrs]	1800–2200	Purple or brown sandstones interbedded with sandy shales.	Comby ridges. Rocky, sandy soil.
	Apison shale..........	Єa	1000+		Narrow, rolling valleys. Stiff clay soil.

Generalized section of Kingston quadrangle east of Clinch and Tennessee rivers.

Period.	Formation Name.	Formation Symbols.	Thickness Ft.	Character of Rocks.	Character of Topography and Soils.
Carb.	Fort Payne chert......	Cp	75+	Beds of chert and cherty limestone.	Knobs parallel with Rockwood ridges; sandy soil with fragments of chert.
Dev.	Chattanooga shale.....	Dc	35	Carbonaceous shale.	
Silurian.	"Rockwood" formation.	Sr	850–1000	Calcareous sandy shale and beds of iron ore. Coarse porous sandstone. Thin bedded sandstone and shale.	High ridges with undulating or rounded summits. Rocky, sandy soil.
Ordovician.	Athens shale..........	Oa	250–400	Calcareous shale weathering yellow.	Level valleys; shallow residual deposits of red or blue clay. Scanty blue clay soil where the limestone beds have low dips, and deep red clay where they are steeply inclined.
	Chickamauga limestone	Oc	1500–1800	Earthy limestones; mottled, purple and gray. Blue flaggy limestone.	
Ordovician. / Cambrian.	Knox dolomite........	€Ok	3300–3500	Magnesian limestone; white, gray or light blue; generally granular and massively bedded; containing nodules and layers of chert.	Low ridges and irregular rounded hills; deep residual deposits of red clay and chert. Red clay soil with a few fragments of chert, grading into white or gray soil, composed almost entirely of chert.
Cambrian.	Conasauga shale.......	€c	0-1500	Blue seamy limestone. Greenish clay shales. Thin beds of oolitic limestone.	Level or rolling valleys. Stiff yellow or bluish gray clay soil.
	Rome formation.......	€r	2100–3000	Greenish or brown shales with thin siliceous layers.	Valleys with low ridges. Thin sandy clay soil.
		[€rs]	[700–1000]	Purple and brown sandstones interbedded with sandy shales.	Comby ridges. Rocky, sandy soil.
	Apison shale..........	€a	1000+	Highly colored calcareous shales; red, purple, green, and yellow.	Narrow, rolling valleys. Stiff clay soil.

Generalized section of Loudon quadrangle south and east of Loudon.

Period.	Formation Name.	Formation Symbols.	Thickness Ft.	Character of Rocks.	Character of Topography.
Carboniferous.	Newman limestone....	Cn	650+	Bluish-gray shale and shaly limestone. Massive blue limestone.	Low, open valleys.
Carboniferous. / Devonian.	Grainger shale........	Dg	1100–1200	Red and yellow sandy shale. Massive white sandstone. Greenish- and bluish-gray, sandy shale and sandstone.	Slopes of high ridges and lines of low knobs.
Devonian.	Chattanooga shale.....	Dc	6–50	Black, calcareous and carbonaceous shale.	Narrow valleys.
Sil.	Clinch sandstone......	Scl	0–100	Massive, white sandstone.	Small ridges and benches.
Ordovician.	Bays sandstone.......	Ob	1100–1300	Red sandstone, calcareous sandstone, and sandy limestone.	Irregular hills and knobs.
	Sevier shale...........	Osv Osvs Osv Osvs Osv	300–400 100–200 400 350–550 450–750	Bluish, calcareous shale and shaly limestone, with lentils of calcareous sandstone. Bluish-gray, calcareous sandstone and sandy shale. Bluish, calcareous shale and limestone. Variegated marble.	Low valleys with uneven surfaces. Ridges and lines of hills. Low valleys and uneven surfaces.
	Tellico sandstone......	Ot	350–900	Bluish-gray and reddish calcareous sandstone and sandy shale interbedded.	Ridges and lines of high hills.
	(Holston marble lentil.) Chickamauga limestone } Athens shale..	Ohl Oa Oc	1000–1200	Variegated marble, blue. calcareous shale, and limestone, grading eastward into blue, calcareous shale, carbonaceous at the base.	Low valleys with slightly uneven edges.
Ordovician. / Cambrian.	Knox dolomite........	€Ok	3500–3800	Magnesian limestone; white, gray, light and dark blue, with nodules of chert.	Broad, cherty ridges and high rounded hills.
Cambrian.	Nolachucky shale......	€n	650	Yellow and brown calcareous shale, with limestone beds.	Flat, open valleys.
	Maryville limestone....	€m	0–250	Massive dark-blue limestone.	Open valleys and lines of low knobs.
	Rogersville shale......	€rg	180	Bright-green clay-shale with a bed of limestone.	Lines of low knobs.
	Rutledge limestone....	€rt	0–200	Massive dark-blue limestone.	Open valleys.
	Rome formation.......	€r [€rs]	500+	Brilliant red, yellow, green and brown sandy and argillaceous shale. Red, yellow and brown sandstone and sandy shale.	Slopes of Rome sandstone ridges. Sharp ridges with notches and gaps.

Generalized section of Loudon quadrangle south and east of Loudon.—Cont'd.

Period.	Formation Name.	Formation Symbols.	Thickness Ft.	Character of Rocks.	Character of Topography.
Cambrian.	Hesse sandstone.......	€h	500+	Fine, massive, white sandstone.	High, sharp-crested mountains.
	Murray shale.........	€mr	300	Bluish-gray sandy shale.	Steep slopes and depressions.
	Nebo sandstone.......	€nb	500–650	Fine and coarse, massive, white sandstone.	High, sharp-crested mountains.
	Nichols shale.........	€nc	800–900	Bluish-gray, sandy shale.	Steep slopes and narrow valleys.
	Cochran conglomerate .	€ch	800–900 100 700	Massive, white sandstone, coarse and fine. Red sandstone and gray sandy shale. Coarse conglomerate with quartz and feldspar pebbles.	High, sharp-crested mountains. Small depressions. High, round-topped mountains and ridges.
	Sandsuck shale........	€s	500+	Bluish-gray, argillaceous shale.	Slopes of Cochran conglomerate mountains.

Generalized section for the Briceville quadrangle.

Period.	Formation Name.	Formation Symbols.	Thickness Ft.	Character of Rocks.	Character of Topography and Soils.
Carboniferous.	Anderson sandstone....	Can	1000+	Sandstone, thin and massive interbedded with sandy and argillaceous shales and thin coal beds.	Flat-topped ridges and mountains with lines of cliffs and ledges. Thin, sandy and clayey soil.
	Scott shale...........	Csc	500–650	Argillaceous and sandy shales with some beds of sandstone and thin coal seams.	Rounded summits and steep slopes of Anderson sandstone mountains.
	Wartburg sandstone...	Cwb	500–600	Interbedded sandstone, sandy shale, argillaceous shale, and coal beds.	Flat-topped spurs, benches, and small ridges, with many low cliffs. Sandy sterile soil.
	Briceville shale........	Cbv	250–650	Black, bluish-gray, and gray, argillaceous shale with small beds of sandy shale, sandstone, and thick coal beds.	Low valleys with small hills and spurs. Thin clay-soil with sandy wash.
	Lee conglomerate......	Cle	500–1500	Massive sandstone with beds of cross-bedded sandstone and conglomerate, a few thin shale beds and thin coal seams.	Sharp, rugged ridges and mountains with many cliffs and ledges. Thin, sandy and rocky soil with much sandstone waste.

Generalized section for the Briceville Quadrangle.—Cont'd.

Period.	Formation Name.	Formation Symbol.	Thickness Ft.	Character of Rocks.	Character of Topography and Soils.
Carboniferous.	Pennington shale..	Cpn	160–400	Calcareous shale, sandstone, and limestone.	Small hollows. Sandy clay-soil.
	Newman limestone	Cn	650–750	Massive blue limestone and a few shale beds. Massive beds of chert and cherty blue limestone.	Rolling ground, small ridges, and a few cliffs on the slopes of Lee conglomerate mountains. Cherty red clay-soil.
Dev.	Chattanooga shale.	Dc	50–80	Black, carbonaceous shale.	Narrow depressions.
Silurian.	"Rockwood" formation.	Sr	400–500	Red and brown, calcareous and sandy shales with local beds of white sandstone and fossiliferous red hematite.	Valleys and sharp, even-topped ridges. Thin, sandy soil.
Ordovician.	Bays limestone....	Ob	160–200	Red, argillaceous and sandy limestone.	Valleys and low slopes. Thin, sandy clay-soil with many outcrops.
	Chickamauga lime stone.	Oc	1600–2000	Blue and gray limestone, argillaceous limestone, flaggy limestone, and calcareous shale. Blue and gray massive limestone with a few nodules of black chert.	Smooth, open valleys. Red and yellow clay-soil. Low rounded hills. Red, clayey soil and chert fragments.
—	Knox dolomite....	€Ok	2800–3500	Magnesian limestone; white, gray, light-blue, and dark-blue, with nodules of chert.	Broad, cherty ridges and high, rounded hills. Deep, red clay-soil with many chert fragments.
Cambrian.	Conasauga shale... { Nolachucky shale.... / Maryville limestone	€c { €n / €m	650–800 (250)	Yellow, red, and brown, calcareous shale, with thin beds of limestone, those at the base assuming the importance of a separate formation in the extreme southeast.	Valleys and slopes of Knox dolomite ridges. Thin, yellow clay-soil.
	Rome formation...	€r	600–800	Bright-colored, red, green and brown, sandy shale interbedded with layers of thin sandstone.	Slopes of sandstone ridges. Thin, brown clay-soil with much sandstone wash.
		€rs	500+	Red, yellow, and brown, sandy shale with thick beds of sandstone.	Sharp ridges with notches and gaps. Thin, sandy soil with ledges and fragments of sandstone.

Generalized section for Maynardville quadrangle, northwest of Walden Ridge.

Period.	Formation Name.	Formation Symbols.	Thickness Ft.	Character of Rocks.	Character of Topography and Soils.
Carboniferous.	Briceville shale........	Cbv	200+	Black, bluish-gray, and gray, argillaceous shale with small beds of sandy shale and sandstone, and thick coal beds.	Flat valleys with small hills and spurs Thin clay soil with sandy wash.
	Lee conglomerate......	Cle	1000–1100	Massive sandstone, in part cross bedded, with conglomerate, a few thin shale beds, and thin coal seams.	Sharp, rugged ridges and mountains with many cliffs and ledges. Thin, sandy and rocky soil with much sandstone waste.
	Pennington shale......	Cpn	150–220	Calcareous shale, sandstone, and limestone.	Small hollows. Sandy clay soil.
	Newman limestone....	Cn	300–600	Massive and cherty, blue limestones with a few shale beds.	Rolling ground, small ridges, and a few cliffs on the mountain slopes. Cherty, red clay soil.
Dev.	Chattanooga shale.....	Dc	100–400	Black, carbonaceous shale.	Narrow depressions.
Silurian.	"Rockwood" formation.	Sr	400–700	Red and brown, calcareous and sandy shales with local beds of white sandstone and fossiliferous red hematite.	Valleys and sharp even-topped ridges. Thin, sandy soil.
Ordovician.	Bays formation.......	Ob	150–250	Red, argillaceous and sandy limestone.	Valleys and low slopes. Thin, sandy clay soil.
	Chickamauga limestone	Oc	1500–2000	Blue and gray limestone, argillaceous limestone, flaggy limestone, and calcareous shale. Blue and gray, massive limestone, with a few nodules of black chert.	Smooth, open valleys. Red and yellow clay soil. Low rounded hills. Red, clayey soil with chert fragments.
Ordovician. / Cambrian.	Knox dolomite........	€Ok	2800–3500	Magnesian limestone; white, gray, light blue, and dark blue, with nodules of chert. Beds of white, calcareous sandstone and sandy marble.	Broad, cherty ridges and high rounded hills. Deep, red clay soil with many fragments of chert and sandstone.
Cambrian.	Conasauga shale.......	€c	600–750	Yellow, red and brown calcareous shale with thin beds of limestone.	Valleys, and slopes of Knox dolomite ridges. Thin, yellow clay soil.
	Rome formation.......	€r	450–600	Bright-red, green, and brown, sandy shale with layers of thin sandstone.	Slopes of sandstone ridges. Thin, brown clay soil with much sandstone wash.
		€rs	1000+	Red, yellow and brown sandy shale and massive sandstone with layers of blue and sandy limestones.	Sharp ridges with notches and gaps. Thin, sandy soil with ledges and fragments of sandstone.

are fossiliferous. The formation is best developed in middle East Tennessee in the Loudon and Knoxville quadrangles, where its thickness is reported to be from 350 to 900 feet. It extends northward in the Maynardville quadrangle north of Knoxville, and also southwestward nearly to Cleveland. This formation receives its name from Tellico River, which cuts a good section through it in Monroe County. The ore in the Tellico varies from a lean sandy material of low grade, to a compact, heavy, lustrous, rich, red ore. Many of the fragments are characteristically slickensided on joint and fracture planes.

Silurian Rocks.

"Rockwood" formation.—The series of beds in East Tennessee to which the term "Rockwood" has been applied in the various geologic folios is composed of locally varying amounts of shale, sandstone, limestone, and red fossil iron ore. Characteristic exposures occur at Rockwood, Roane County. Much of the shale is calcareous and some of the sandstone is ferruginous. The limestone occurs chiefly in the upper third or half of the formation where it is usually associated with the most important of the ore beds. Thick bedded sandstones, when present at all, are confined to the upper part of the lower half. A considerable body of red weathering shale, or impure argillaceous limestone with bands of red shale, often forms the basal part.

In Tennessee the "Rockwood" formation, varies in thickness from a few feet to over 1,000 feet, the greatest observed thickness being in the synclinal belts in the Great Valley, in which it ranges from 400 to 700 feet in the vicinity of Maynardsville to nearly 1,100 feet in Whiteoak mountain southwest of Cleveland. On the east side of the Great Valley in the foothills of the Appalachian Mountains the typical "Rockwood" is wanting altogether. On the west side below the Cumberland escarpment it is not so thick as in the middle of the valley, the thickness varying here between 400 and 600 feet. Farther westward the thickness seems to decrease rapidly, the maximum in the Sequatchie valley being under 250 feet. As the formation rests unconformably on various Ordovician formations a part of the noted westerly thinning is due to overlap unconformity. Another but doubtless smaller part of the loss is probably occasioned by erosion prior to the deposition of the black Chattanooga shale, which in East Tennessee is usually the first formation following the "Rockwood." But the greatest part of the loss in thickness westward from Whiteoak mountain is probably to be ascribed to absence of beds which are well developed in the latter syncline.

The iron ore beds are present mainly in the upper third or half of the formation, in other words from 60 to 200 feet beneath the base of the overlying Chattanooga shale. The ore beds are not at all constant in

number, apparent position, thickness, or chemical composition. There may be as many as five ore seams or beds in a single section or there may apparently be none. There is hardly a place, however, where the "Rockwood" formation is represented that some trace of an iron ore seam cannot be found after careful search. The ore occurs in seams varying in thickness from a fraction of an inch to beds 6 or 7 feet thick or of even greater thickness. Where the greater thickness is reached the bed is generally divided by thin shale partings into several benches and in places these shale partings may become sufficiently thick to separate the several benches of ore into so many distinct seams. The ore beds consist of layers composed partly of fossils in complete or fragmentary condition which are wholly or partially composed of iron oxide and alumina, and partly of fine to coarse silica sand coated and cemented together by iron oxide, calcium carbonate and alumina. The whole mass of the ore contains much crystalline calcium carbonate in places, especially where unweathered. Where the content of ferric oxide (Fe_2O_3) falls below 30 per cent (21 per cent of metallic iron) the material can hardly be regarded as an ore. The ores themselves will be described in greater detail on pages 74 to 81.

Fossils occur more or less abundantly at various horizons in the formation, the total number of species so far collected making up a large and varied fauna. Organic remains are especially abundant in the upper limestone and in the iron ore beds associated with it. According to E. O. Ulrich, these establish the approximate equivalency of the upper part of the typical "Rockwood" with the lower part of the iron-bearing series in the Birmingham, Alabama, district. On the basis of the fossil evidence Mr. Ulrich concludes that the main ore bed of the typical "Rockwood" corresponds essentially to the Irondale seam in Alabama, and that the whole of the typical "Rockwood" formation of Tennessee is older than the base of the Big Seam in the Birmingham district. Mr. Ulrich now believes also that the Clinch sandstone in the northern part of the valley of East Tennessee and in Virginia corresponds in age to the middle and upper parts of the typical "Rockwood," and that the typical "Rockwood" as a whole is the southern Appalachian equivalent of the Medina of New York. Finally he states that the beds mapped or described as "Rockwood" and Clinch at Cumberland Gap and in Powell Mountain include at the base a sandstone corresponding, as long ago suggested by Safford, to the sandstone to which Safford gave the name Whiteoak Mountain sandstone, and above this shale and thin bedded sandstone, including one or more beds of iron ore, that are unmistakably of Clinton age. The upper part of the typical "Rockwood," which includes the main "Rockwood" ore bed, seems to be entirely absent in these northern ridges.

The paleontologic and stratigraphic studies of Mr. Ulrich may lead to such changes in the conception of the formations heretofore considered to be of Clinton age in Tennessee and Alabama that a presentation of his evidence and conclusions belongs more properly in a scientific paper, where the subject can be given adequate space, than it does in this bulletin, which is devoted solely to an economic consideration of the ore beds. It should be stated here, however, that the conclusions of Mr. Ulrich have an important bearing on the economic questions involved, as well as on the more purely scientific questions relating to the geologic history of the deposits. The very considerable differences between the "Rockwood" ore and the "Big Seam" of the Birmingham district are more readily understood if there be a difference in geologic age, although they may equally well be due to their great geographic separation.

While it is unnecessary to publish in the present bulletin all of the newer views advanced by Mr. Ulrich, it is profitable to present from his data the following generalized section, and nine detailed sections of the "Rockwood" formation in East Tennessee, and a generalized section of the Clinton formation in north central Alabama. The relations and distribution of the various groups of sediments, aside from their characteristic fossil contents, is strongly suggestive of the propriety of, if not the necessity for, subdividing the "Rockwood" as formerly described.

The following generalized section of beds formerly referred to the "Rockwood" formation has been constructed from facts as found at five representative localities in southeast Tennessee, viz.: Rockwood, Chamberlain, Whiteoak Mountain near Cleveland, and Chattanooga, and at the abandoned Inman mines. The first four places are in the main Appalachian Valley, the last in Sequatchie Valley.

Generalized section of the "Rockwood" formation in southeastern Tennessee, from notes by E. O. Ulrich.

Chattanooga shale.	
Great hiatus.	
"Rockwood" formation:	Feet.
7. Arenaceous, greenish to brown shale and thin platy sandstone, locally with thin ore beds. Thin or absent in upper Sequatchie valley	0–200
6. Main ore bed and associated limestone, usually present but wanting in northern part of Sequatchie valley	0–10
5. Shale, a little thin sandstone, and one or two cherty fossiliferous limestone beds, best developed at Rockwood and in the Sequatchie valley, absent in the Whiteoak Mountain syncline at Chamberlain and Cleveland, and thin or wanting in the vicinity of Chattanooga	0–120+
4. Arenaceous shale and platy sandstone, occasional layers filled with typical Medina fossils; at base usually a bed of massive sandstone (Rockwood sandstone member of Hayes). Best developed in the Whiteoak Mountain syncline, absent at Rockwood, Chattanooga, and in the Sequatchie valley	0–420
Hiatus.	

	Feet.
3. Interbedded thin limestone ledges and shale, with a sandy bed near base and occasionally beneath that a highly ferruginous suboolitic layer. Locally best developed in the southern part of the Sequatchie valley	0–67
2. Red shale, argillaceous and more or less limy sandstone and arenaceous or argillaceous limestone, the last chiefly near the base and often fossiliferous; locally with a bed of lean fossiliferous ore. Generally present	50–500+
Hiatus.	
1. Arenaceous shale and thin beds of shaly limestone, the latter abundantly fossiliferous as a rule; of Maysville age. Absent, except in the Whiteoak Mountain syncline, where it was included in the "Rockwood."	0–300
Aggregate maximum thickness of "Rockwood" formation	1617

0–500+ feet greenish drab soft shale in the Whiteoak Mountain syncline, corresponding to the Eden shale of Ohio. (Mapped as Athens shale by Hayes.)

Hiatus.

Chickamauga limestone, the top usually of late Trenton age.

The following are among the detailed sections of the "Rockwood" studied and reported by Mr. Ulrich.

I. *Detailed section of the "Rockwood" formation at Rockwood, Tennessee.*

Chattanooga shale.
Hiatus.
'Rockwood" formation:

Divisions 5, 6 *and* 7 *of the generalized section:*	Ft.	in.
11. Greenish soft shale with a few sandy layers	125	
10. Ferruginous, argillaceous limestone containing *Tentaculites*		3–7
9. Greenish shale with occasional thin sandy leaves	35	
8. Main iron ore bed	3–5	
7. Greenish shale and thin platy layers of sandstone	50	
6. Cherty limestone with a little shale, the chert in 1-3 inch plates, argillaceous, ferruginous, soft, fossiliferous	4	
5. Shale	15	
4. Calcareous thin-bedded, shaly sandstone with *Orthis euorthis*	20	
3. Thin-bedded sandy chert, thin sandstone and shale, sparingly fossiliferous, *Whitfieldella* cf. *intermedia, Orthis euorthis*	30	
2. Mostly shale, in part slightly arenaceous	34	
1. Calcareous thin-bedded sandstone, light-gray and red, the colors in mottled or alternating arrangement	6–8	
Thickness about	326	

Hiatus (Division 4 of generalized section wanting).

Divisions 2 and 3 of the generalized section:	Ft.
7. Argillaceous, fine grained, light colored limestone pierced with delicate Scolithus tubes	2–3
6. Shale, not well exposed	4
5. Argillaceous limestone	2
4. Greenish and brown shale	10
3. Red calcareous beds weathering to an argillaceous, yellowish gray or red sandstone	10
2. Red clay, probably residual after calcareous shale and argillaceous limestone	25
1. Strongly weathered residual clays, yellowish and sometimes red, probably derived from an argillaceous limestone	300+
Thickness about	354+
Total thickness of "Rockwood" about	680

Hiatus.

Chickamauga (Ordovician) limestone.

II. *Section of the "Rockwood" formation between Kingston and Chamberlain, Tenn.*

Fort Payne chert and Chattanooga shale.

?Hiatus.

'Rockwood" formation:

Divisions 6 and 7 of generalized section:	
2. Closely interbedded thin platy sandstone and olive-green sandy shale, very sparingly fossiliferous, about	200
1. Fossiliferous iron ore bed and associated, often crossbedded, limestone, both richly charged with Bryozoa and Brachiopoda characteristic of the "Clinton" of Ohio; base somewhat irregular	3–5
Thickness about	205

Probable hiatus (bed 5 of generalized section being absent or at least unrecognizable).

Division 4 of generalized section:	
6. Sandstone	2
5. Shale	12
4. Sandstone, in 3-15 inch ledges	16
3. Sandstone and shale interstratified, certain layers filled with Medina fossils	45
2. Sandy shale	15
1. Sandstone and shale, not well exposed on east limb of syncline where overlying beds were measured, about	215
Thickness about	305[1]

?Hiatus.

[1]On the west limb of the syncline, along the main road about 5 miles south of Kingston, this division seems to contain less shale and to be only about 200 feet thick. At the base is a massive 12-foot ledge of sandstone which was not observed on the east limb. A hurried search revealed at least two abundantly fossiliferous layers in the upper 50 to 75 feet of the formation.

Divisions 2 and 3 of generalized section:

	Ft.
2. Calcareous shale and cobbly impure limestone the latter with an upper Richmond coralline and bryozoan fauna, not measured, about	50
1. Mostly red, limy and argillaceous sandstone, about	300
Thickness about	350
Total thickness of "Rockwood" formation	860
Hiatus.	
Athens shale of Hayes:	
2. Sandy shales and impure limestone, with abundant fossils of the age of the Fairview formation of Bassler as described in the Cincinnati section	300+
1. Shale of Eden age	500+
Chickamauga limestone, great thickness.	

III. *Section in Whiteoak Mountain along the Southern Railroad, between Ooltewah and Cleveland, Tenn.*

Chattanooga shale.
Hiatus.
"Rockwood" formation:

Divisions 6 and 7 of generalized section:

Red and greenish shales alternating with thinner beds of fine-grained, thin platy sandstone; contains near the base one or more thin seams of fossiliferous iron ore regarded as representing bed 6 of the generalized section. Thickness estimated, approximately	200
?Hiatus (bed 5 of generalized section absent).	

Division 4 of generalized section:

Sandstone and shale interbedded, mostly of reddish-brown and green colors, the sandstone predominating, most of the layers thin and even-bedded, others thick especially one at or near the base which is hard and brown and 8 feet or more in thickness. Occasional layers which are porous and evidently were calcareous originally, are filled with fossils. So far as observed these are confined to the upper third. Thickness believed to be approximately as given by Safford (Geol. Tennessee, p. 302)	420
?Hiatus.	

Divisions 2 and 3 of generalized section:

2. Greenish shale interbedded with shaly blue limestone containing Richmond fossils. Thickness as given by Safford	130
1. Red or dark reddish-brown argillaceous and slightly arenaceous limestone with occasional greenish layers and splotches	150+
Thickness	280+
Total thickness of "Rockwood" formation	900+

IV. *Section near St. Elmo (suburb of Chattanooga, Tenn.).*

Chattanooga shale.
Hiatus.
"Rockwood" formation:

Divisions 5, 6 and 7 of generalized section:	Ft.
4. Thin platy sandstone and sandy shale	60
3. Several thin (5 to 9 inch) beds of oolitic iron ore, in sandy shales	10
2. Sandy yellowish shale	8
1. Concealed, probably including base of formation which at a nearby locality is formed by a 3-foot bed of soft greenish-gray to brown thin-plated sandstone, about	10
Thickness	88

Hiatus.

Division 2 of generalized section:	
5. Shaly beds with one or more 1 to 3-foot beds of highly fossiliferous rotten sandstone which doubtless were originally very calcareous. Fossils include a large *Platystrophia*, *Heberterlla* sinuata var., several Trepostomatous Bryozoa, *Opisthoptera fissicosta*, and other pelecypods characteristic of the lower member of the Waynesville beds of Nickles as described in Ohio	4–15
4. Ferruginous impure limestone, occasionally good but thin beds of ore, variably interbedded with blue limestone and shale, all more or less fossiliferous, the species much the same as in overlying bed	8
3. Mostly shales, with layers of argillaceous or slightly sandy limestone the latter with large *Platystrophia* and other fossils indicating essentially the same fauna as above	45
2. Similar to above but limestone, which decomposes readily and leaves an arenaceous clay, proportionately more abundant	10
1. Thin-bedded sandstone, the basal layers thickest and in irregular contact with the underlying Chickamauga limestone	0–4
Thickness	82
Thickness of "Rockwood" in the bands outcropping on each side of the northern extremity of Lookout Mountain	160–200

Hiatus.

Chickamauga limestone; (various beds of upper Trenton age).

V. *Section along N. C. & St. L. R. R. west from Wauhatchie, Ga.* (By Charles Butts).

Fort Payne chert.	Ft.
Concealed, with 10 to 15 feet of Chattanooga shale probably at the top and the remainder Silurian shale. The latter perhaps in part of Clinton age..	80

Divisions 5, 6 *and* 7 *of generalized section (exposed):*

7. Green shale		20
6. Iron ore with shale partings	8 inches	3–4
5. Shale	7 inches	
4. Iron ore	30 inches	
3. Shale with fossiliferous limestone, with *Streptelasma geometricum*		10
2. Iron ore, lean		½
1. Shale and thin limestone, sparingly fossiliferous		50+
Thickness about		85+
Hiatus.		

Divisions 2 *and* 3 *of generalized section:*

10. Heavy crystalline ferruginous limestone with late Richmond fossils (3 to)	10
9. Shale and rough, in part cobbly weathering limestone, the latter full of *Rhombotrypa quadrata* and other Richmond Bryozoa	2
8. Greenish shale	10
7. Rotten, originally calcareous, sandston , highly fossiliferous (represents bed 5 of same division in preceding section)	2
6. Shaly limestone	2
5. Concealed, probably not to exceed	10
4. Green shale	3
3. Concealed, apparently not more than	5
2. Argillaceous, grayish-blue limestone, containing large *Platystrophia* in abundance	20
1. Concealed, about	10
Thickness	74
Total thickness of "Rockwood" about	160

Chickamauga limestone, thin bedded, highly fossiliferous limestone of upper Trenton age.

VI. *Section at foot of Raccoon Mountain, on N. C. & St. L. R. R., a few miles west of section V. (Amended after Safford, Geology of Tennessee, p. 304).*

	Ft.
Chattanooga shale, with 1 foot sandstone at base	12
Hiatus.	
"Rockwood" formation:	
3. Greenish shale	22
2. Iron ore, with shaly partings (compare "Hickory Nut" seam in central Alabama)	1½
1. Fine sandstone, somewhat ferruginous, in part inclining to be shaly. Contains *Pentamerus oblongus*	6
Thickness	29½
?Hiatus.	

Divisions 5, 6 *and* 7 *of gen ralized section:*

7. Greenish shale with occasionally thin ferruginous layers lean ore) some layers more or less calcareous	67
6. Calcareous dyestone, alterna ing with shale; fresh, the dyestone has the aspect of deep red limestone, is fossiliferous, and much of it oolitic, weathers into a rather open iron-ore; one layer 12 inches thick. In all.	4
5. Greenish shale much like second bed above; contains one or two seams of lean calcareous ore; in its lower part are *Leptæna rhomboidalis, Dalmanella cf. elegantula* and other fossils that are characteristic of this zone	21
4. Lean calcareous ore	½
3. Shale and thin limestones alternating	14
2. Lean calcareous ore	½
1. Alternating thin limestones and shales; freshly quarried, the whole mass is blue with the limestone predominating; contains *Atrypa marginalis, Leptæna rhomboidalis,* and other fossils	112[1]
Thickness about	219

Division 2 *of generalized section:*

Reddish, argillaceous limestone, with large *Platystrophia*	100
Thickness perhaps	162
Thickness of "Rockwood" about	410½

[1]The two fossils here listed probably belong in the upper part of this bed. Safford (op. cit. p. 253) mentions other fossils which, judging from the names applied to them, suggest that the lower part of the bed is of late Richmond age and therefore referable to Divisions 2 and 3.

VII. *Section between abandoned Inman mines and Sequatchie River, 4 to 7 miles east of Jasper, Tenn.*

Fort Payne chert.
Hiatus.

	Ft.
Chattanooga shale	10–15
Hiatus.	
"Rockwood" formation:	
Divisions 5, 6 *and* 7 *of generalized section:*	
5. Greenish shale with thin layers of calcareous and argillaceous fine grained sandstone or sandy limestone, a few of which contain fossils, among them undetermined species of *Dalmanella, Rhipidomella, Whitfieldella, Zaphrentis, Phylloporina angulata* and *Buthotrephis* cf. *gracilis* and *crassa*	25–40
4. Ore bed and associated limestone, both highly fossiliferous; *Rhinopora verrucosa, Phænopora expansa, Ph. multifida, Leptæna, rhomboidalis, Hebertella, daytonensis, Stricklandina triplesiana, S.* cf. *planus, Illænus daytonensis, Calymene vogdesi,* and others	3–5
3. Uneven, sandy and calcareous plates interbedded with greenish shale and thin, relatively pure, cobbly weathering limestone, the last highly fossiliferous, with three or four species of *Streptelasma* and *Zaphrentis, Heliolites* sp., *Favosites,* cf. *favosus, Plectambonites prolongatus, Strophomena* n. sp., *Dalmanella* cf. *elegantula, Rhipidomella* n. sp., *Hebertella* cf. *insculpta* and *fausta, Platystrophia* sp., *Triplesia ortoni, Rhynchonella* cf. *acinus,* and *R.* cf. *neglecta*	20
2. Irregular cherty layer with fossil corals	20
1. Greenish shales and a few subcrystalline limestone plates; also a few sandy plates with fuccids like *Buthotrephis crassa*	30
Maximum thickness	115
Hiatus.	
Divisions 2 and 3 of generalized section:	
17. Crystalline, greenish, fossiliferous limestone with specks of glauconite and small phosphatic pebbles. *Fenestella* sp., several small branching trepostomatous Bryozoa, *Plectambonites* aff. *sericeus, Leptæna tenuistriata*	0–3
16. Limestone alternating with shale	12
15. Arenaceous blue limestone, very hard	13
14. Crystalline bluish-gray limestone with *Platystrophia* cf. *acutilirata* and ramose Bryozoa as In	1
13. Arenaceous limestone like No. 15	14
12. Crystalline blue limestone containing *Bythopora delicatula, Strophomena planumbona,* and *Cyclonema bilix*	3½
11. Bluish shale and thin irregular seams of fossiliferous limestone, with *Plectambonites* sp., *Leptæna tenuistriata, Strophomena planumbona, Rhynchonella dentata, Rhynchotrema cafax*	14
10. Sandy, hard, blue limestone with a few ramose Bryozoa	5½
9. Ferruginous bed, oolitic and sparingly fossiliferous, sometimes almost rich enough to be an ore	2+
(Probably small break in sedimentation.)	

	Ft.
8. Arenaceous, resistant, hard limestone at top but decomposing more readily beneath upper 2 feet	11½
7. Mainly fine-grained cobbly weathering limestone	10
6. Rather massive, finely laminar and sandy limestone; contains large ramose bryozoan, long-hinged *Platystrophia* and *Lophospira* aff. *bowdeni*	8
5. Cobbly weathering limestone	3
4. Uneven-bedded, rather massive but cobbly weathering argillaceous limestone filled with large *Platystrophia*. A large *Lophospira* in top surface and an undetermined *Modiolopsis* in basal foot or so	12
3. Rather platy bluish gray limestone, largely composed of fragmentary fossils	6
2. Greenish to blue, thin-bedded, shaly and arenaceous limestone with few fossils, weathering into reddish-yellow shale	15
1. Red shale interbedded with greenish and light-blue shale and sandy thin-bedded impure limestone. One of the latter contains *Scolithus* tubes one-sixteenth inch in diameter, 2 inches long, and one-half to one inch apart	9
Thickness[1]	142½
Total thickness of "Rockwood"	257½

Hiatus and unconformity.

Limestone of Ordovician Age.

Rather heavy-bedded, argillaceous and slightly arenaceous limestone with *Amplexopora columbiana* and other Bryozoa in basal layers	0–6½

[1]The lower member is unusual in this section in that it contains much more limestone than is seen elsewhere. The red color also is relatively inconspicuous being almost confined to the lower 25 feet.

VIII. *Section in the northern part of Sequatchie Valley compiled from observations by Charles Butts and E. O. Ulrich at Walkers Knob and in Cross Mountain.*

Chattanooga shale, usually 15 to 20 feet.
Hiatus.
"Rockwood" formation:

Division 5 of the generalized section:	Ft.
Thin-bedded, gray, crystalline limestone and more shaly greenish limestone with layersof chert developed especially in weathered sections. In the Walker Knob section, where the exposure is fresh, the chert is confined to a 4-inch layer at the base, but in other sections, as at the summit of Cross Mountain a few miles to the northwest, the chert is distributed through the whole thickness of the bed[1]. Cup corals of the genus *Streptelasma* locally abundant; other fossils are *Favosites favosus, Propora?* sp., *Stromatopora?*, large columnals of an unknown crinoid, *Rhinopora verrucosa, Orthis euorthis, Dalmanella* aff. *elegantula, Platystrophia daytonensis, Hebertella daytonensis, Strophomena?* sp., *Plectambonites prolongata, P.* sp. undet. (small), *Leptina rhomboidalis, L.* aff. *unicostata, Schuchertella hanoverensis, Rhynchonella janea?, Atrypa marginalis, Whitfieldella* cf. *umbonata, W.* cf. *cylindrica*	15–20+
Thickness	20+

Divisions 2 and 3 of generalized section:	
8. Greenish argillaceous limestone, weathering shaly, with a bed 10 feet above the base containing delicate Scolithus tubes	60
7. Red shale	5
6. Greenish argillaceous limestone	25
5. Red shale	1
4. Greenish argillaceous limestone	10
3. Calcareous greenish sandstone, with a few layers of fine-grained gray impure limestone	40
2. Argillaceous bluish gray limestone, massive in fresh exposures, but weathering readily; a large and variable form ot *Platystrophia* very abundant, with *Hebertella* aff. *sinuata, Stigmatella* sp., and a ramose bryozoan less common	20
1. Greenish argillaceous and shaly limestone	20
Thickness	181

Hiatus.
Ordovician limestone.

[1]About 2½ miles north of Pikeville and just west of the great thrust fault of Sequatchie valley is an outcrop of Chattanooga shale with a thick chert formation on either side. One of these chert formations contains characteristic Fort Payne fossils and is accordingly referred to that age. The other, although something like 200 feet of it is fairly well exposed, has so far afforded but a single good fossil. But as this specimen is of the narrowly diagnostic *Orthis euorthis* it is thought sufficient to establish the age of the lower chert as Silurian and probably as corresponding to a part of the "Rockwood" formation. Judging from the scant facts in hand it is suggested that either the usually thin chert bed of the "Rockwood" thickens rapidly westward from the center of the valley or that the whole formation is represented in that direction by profusely cherty limestone. Regarding the above section it should be noted that elsewhere in the northern part of the Sequatchie valley the upper part of the "Rockwood" is much thinner, not exceeding 20 feet so far as observed. Also that the formation is represented only by a middle or upper part of bed 5 of the generalized section, p. 32. This explains the absence of the iron ore member (bed 6 of the generalized section) in the middle and northern parts of the Sequatchie valley.

IX. *Section in vicinity of Mulberry Gap in Powell Mountain Hancock County, Tennessee.*

Shale of Genesee age in Blackwater valley.
Hiatus.
Hancock limestone, about 120 feet.
Hiatus
"Rockwood" formation:

	Ft.
Greenish shale and thin-bedded, occasionally ripple-marked sandstone, brown, red, gray or greenish, with an oolitic iron ore bed near the base. Fossils abundant in upper half, marked especially by *Calymene clintoni* and *Beyrichia lata*	
Thickness estimated at	300+

Division 4 of generalized section:

Brown and red, mostly thin-bedded sandstone, some of the layers highly ferruginous, others finely conglomeratic, approximately	100
Rather massive, light-gray, in part finely conglomeratic, sandstone, a few fossils of upper Medina species observed, about	90
Thickness about	190

Probably Division 2 of generalized section:

Reddish argillaceous limestone and calcareous shale, poorly exposed, probably less than 100 feet. Similar beds occur to the north at Cumberland Gap where a Richmond fauna has been found in them.

X. *Generalized section showing strata which have heretofore been assigned to the Clinton formation in Central Alabama.*[1]

Fort Payne chert.
Hiatus.
Chattanooga shale and often beneath this a thin representation of Frog Mountain sandstone (of Oriskany age).
Hiatus.
Clinton formation:

Beds above division 7 of generalized section, p. 32

11. Interbedded greenish shale and thin sandstone, containing *Dalmanites limuturus* and other Rochester shale fossils	0–50
10. Sandstone, medium thick-bedded, reddish, ferruginous, in part lean iron ore	37
9. Greenish shale interbedded with calcareous sandstone	38
8. Ferruginous, thick-bedded sandstone, in part calcareous	27
7. Shale	20
6. Sandstone with *Pentamerus oblongus*, especially in basal 4 feet	13

[1]The data for the strata above the "Big seam" are compiled mainly from sections at and to the southwest of Bessemer, those for divisions 5, 6, and 7, from Red Mountain near Birmingham.

	Ft.
5. Lean to fair ore—"Hickory nut seam"—in part filled with *Pentamerus*	0–4
4. Ferruginous, occasionally cross-bedded sandstone	20
3. Iron ore (Ida seam)	0–5
2. Sandstone chiefly, in part thick-bedded and ferruginous	10–38
1. Iron ore with shale partings—Big seam—sandy and low grade in part but with one or two benches each 6–12 feet thick that are minable; fossils sometimes very abundant	16–40
Aggregate maximum thickness of beds above division 7 of generalized section	292

Divisions 5, 6 and 7 of generalized section, page 32.

7. Shale, chiefly interbedded with thin layers of argillaceous sandstone, very sparingly fossiliferous	10–40
6. Iron ore ("Ironade seam"), platy, extremely fossiliferous the fauna composed chiefly of Bryozoa marking the *Rhinopora verrucosa* zone	2–5
5. Heavy-bedded sandstone, rather soft	8–12
4. Thin-bedded soft sandstone	2
3. Ferruginous and shaly soft sandstone, originally calcareous, full of fossils similar to those in the overlying........seam	0–2
2. Gray to brownish green, slightly calcareous, massive sandstone, the lower fourth or third having a peculiar spheroidal structure appearing as though made up of large and small concentrically marked boulder-like masses. From the middle and upper parts of the bed a fauna of 17 species was procured. Most of these are unknown elsewhere but the others are species found in Tennessee and in Kentucky and Ohio. The bed seems to be very local in its distribution having been observed so far only between Lone Pine Gap and the Green Spring mine near Birmingham. Here it wedges out in the space of a few hundred feet. Thickness	0–10
1. Shaly sandstone with thin layers of arenaceous shale and relatively thick (6 to 20 inches) of sandstone. Fossils were found near the top and at the base and in both horizons they were of "Rockwood" species; but the collections are insufficient to decide whether the bed is as old as division 4 or not	30–35
Maximum thickness	106

Hiatus.

The above beds are underlain locally by various Ordovician shales and limestones.

Devonian and Carboniferous Rocks.

Chattanooga shale (*Devonian*).—Overlying the "Rockwood" formation is the Chattanooga shale, a thin formation of shale representing Devonian sediments. Typical exposures of this shale appear in the north end of Cameron Hill in Chattanooga, from which it takes its name.

The Chattanooga shale has a remarkably uniform character throughout the red iron ore region of East Tennessee. It varies in thickness from 6 to 500 feet, but ranges generally from 12 to 50 feet. The upper 3 or 4 feet of the shale are usually dark gray in color and in many places carry a layer of round concretions about 1 inch in diameter. The remainder of the shale is jet black and rather brittle, and when freshly broken emits a strong odor resembling that of petroleum.

This shale, on account of its distinctive and striking appearance, has attracted much attention from miners, and has been prospected in many places for coal, and for various ores, especially silver and copper. Although it contains a large proportion of carbonaceous matter, which burns when placed in a hot fire, the proportion is not sufficient to render it a fuel, and no true coal is ever found associated with the shale. Small concretions of iron pyrites which it generally carries have given rise to the commonly accepted but wholly erroneous belief that the shale carries ores. Prospecting in this shale has always been attended by failure, since there is nothing of present economic importance contained in the formation. The only importance of the shale is as a starting point in prospecting for the "Rockwood" iron ore which occurs stratigraphically from 25 to 200 feet below it throughout considerable areas.

Grainger shale (*Devonian and Carboniferous*).—Overlying the Chattanooga shale in some regions, is the Grainger shale, a formation which derives its name from Grainger County, Tennessee, where it is well displayed. The formation is exposed chiefly in the foothills along the northwest base of Clinch, Powell and Chilhowee mountains in the Loudon, Knoxville, Maynardville and Morristown quadrangles. It comprises flaggy sandstone, sandy shale, and sandstone, with white sandstone and red and brown sandy shale at the top. In places certain of the flaggy sandstone beds are so ferruginous as to constitute a siliceous iron ore, as for instance, southeast of Maryville. This formation ranges from 900 to 1,200 feet thick, but maintains a nearly even thickness for long distances. Fossils which have been found in the Grainger shale in regions toward the northeast indicate that its upper part is of Carboniferous (Mississippian) age, while a Devonian age for its lower portion is indicated by the presence of Devonian fossils. Fossils found in the so-called iron ore beds southeast of Maryville have been determined by E. O. Ulrich to be of Mississippian age. (See notes in connection with description of this ore on page 152.)

Limestone of the Newman, Fort Payne and Bangor formations—The other Carboniferous rocks that are of economic importance in connection with the red iron ore are limestones of Mississippian age and coal-bearing sandstones and shales of Pennsylvanian age. Since this report does not deal with coal, only certain limestones that are of value as a reference horizon or for fluxing material will be mentioned here, viz., the Fort Payne, Newman, and Bangor.

Immediately above the Chattanooga shale along the base of the Cumberland escarpment and in Sequatchie Valley are beds of siliceous and cherty limestone. From the southern border of Tennessee as far northeast as the dividing line between the Kingston and the Loudon quadrangles, or about 3 miles northeast of Harriman these beds are termed the Fort Payne chert. The thickness of the Fort Payne ranges here from 60 to 200 feet, but in the valley ridges in the Cleveland quadrangle it reaches a thickness of 350 feet. Northeastward beyond Harriman, along the Cumberland escarpment, through the Loudon, Briceville, and Maynardville quadrangles, the siliceous and cherty limestone beds succeeding the Chattanooga shale are termed the Newman limestone, but included in this formation are a considerable thickness of massive, blue limestone above the cherty basal portion. The Newman varies from 300 to 750 feet thick. Above the Fort Payne chert lies a considerable thickness, 750 to 900 feet, of massive blue limestone, grading into shale at the top. This formation is known as the Bangor limestone. The Fort Payne strata pass by gentle gradations into the Bangor strata. For practical purposes the Fort Payne and Bangor formations may be regarded as occupying approximately the same horizon as the Newman limestone. These formations are of Mississippian ("Lower Carboniferous") age, and lie below the Pennsylvanian, or coal-bearing rocks. The Mississippian limestone and chert contain generally an abundance of fossils such as fragments of crinoids, and shells of molluscs and brachiopods, a fact which renders them easily distinguishable from the sparingly fossiliferous limestone and chert of the Knox. Incidentally the fossiliferous character of the Mississippian beds is of great practical value when it is desired to determine whether the "Rockwood" iron ore lies below a given area or whether it has been faulted against an area of Knox dolomite. Both the Newman and Bangor limestones occupy steep mountain slopes and are advantageously situated for quarrying.

STRUCTURE.

Definition of terms.—The materials forming the rocks of this region were deposited on the sea-bottom, consequently they must originally have lain in nearly horizontal layers. At present the beds or strata throughout a large part of the region are not horizontal but are inclined at various angles. The angle at which beds of rock are inclined from the horizontal is called the dip, and the direction in which the edge of an outcropping bed of rock extends, measured in a horizontal plane, is called the strike. A bed which dips beneath the surface at one place may curve upward elsewhere to the surface; such a fold, sag or trough between two outcrops is called a syncline. Again, beds may arch upwards instead of downwards, forming what is called an anticline. (See figs. 10, and 20.) A synclinal axis is a line running lengthwise through the lowest points of a synclinal trough, and toward which the rocks dip on either side. An anticlinal axis is a line running lengthwise through the highest points of an anticlinal arch away from which the rocks dip on either side. Its local angle of inclination is called the pitch, and is usually but a few degrees. Simple folded structure consists of a series of regular anticlines and synclines. In areas of folded rocks the strata may be broken and an anticline be thrust over upon a syncline. Such a break is called a fault. (See fig. 21.) A simpler form of fault occurs where nonfolded or gently folded beds are dislocated so that beds of different stratigraphic position are brought into juxtaposition along the fault plane. (See fig. 19.) If the syncline be buried beneath the overthrust mass of the anticline the strata at the surface may all dip in one direction, so that they appear to have been deposited in a continuous series, and it then requires careful study of the individual beds to determine their true structual relations. Many of the folds and faults in this region are of great magnitude, their dimensions being measured by miles, but similar structures also occur on a very small scale, their dimensions being measured by feet or inches, and in extreme cases they may be microscopic in size.

Cumberland Plateau.—The rocks that form the Cumberland Plateau lie in general nearly horizontal, but over broad areas the apparently horizontal rocks actually have slight dips. For instance, that part of the plateau lying between Sequatchie Valley and the Great Valley, extending northward from Tennessee River at Chattanooga to beyond Dayton and Pikeville, and known as Walden Ridge, is in reality a shallow syncline or basin, the southeast and northwest borders of which dip more

or less steeply toward each other for short distances but become nearly flat in the interior of the basin. There are certain other prominent structural axes within the plateau region, among which may be mentioned the Sequatchie Valley anticline, and the Fork Mountain and Pine Mountain faults. It is chiefly in the foothills below the eastern border of the plateau that the iron ore is accessible, and here the rocks are generally steeply tilted toward the northwest or nearly vertical and in places they have been thrown into crumpled and overturned folds and even have been faulted considerably. The general structure of this portion of the field is shown in the structure sections, Figs. 10, 21, 25, and 26, and certain details concerning it are given in the descriptions of the ore mines near Rockwood.

Great Valley.—In the valley regions the rocks have been steeply tilted, bent into folds, broken by faults, and on the eastern margin they have to some extent been altered into slate. The folds are long and straight, and are usually closely squeezed, often to such an extent that on the west side of the anticlines the rocks have been bent up until nearly vertical and then pushed over beyond the vertical. Associated with the overturned anticlines are many faults. Like the arches from which they are formed by the breaking of the latter the faults are long and straight. They are generally situated on the northwest side of the anticlines, since that side was less able to resist the horizontal pressure in the crust of the earth which is considered by geologists to have proceeded from the southeast. The dips in the valley range from shallow to vertical and thence to 50° overturned. The average fold dips much more steeply on the overturned side that on the southeast limb. The amount of displacement varies from a few feet to more than 3 miles, a fault displacement of between one and three miles being not at all uncommon. Some of the folds in the Great Valley are of economic interest in that they contain iron ore-bearing formations. Among these folds are the syncline of Whiteoak Mountain, those near Barnardsville and Chamberlain, and the one near Euchee. Cross sections illustrating the position and structure of the beds in valley areas are shown in Figs. 13 and 20.

THE RED IRON ORES.

General statement.—By the term "ore" in this report is meant such ferruginous material as may have a value either at present or in the near future as a source of iron, irrespective of whether or not it occurs in quantities sufficient to mine. At present ores averaging less than 25 per cent of metallic iron are not charged into blast furnaces in any considerable quantities, and ores as lean as this can not be used economically unless they carry more than enough lime to flux them, and are also used in connection with richer ore. Since there are enormous reserves of ore carrying 25 or more per cent of iron available in the Southern Appalachians, it seems hardly necessary in this report to consider as an ore anything leaner than the 25 per cent grade. It is, however, difficult to draw a rigid line. For instance, other things being equal, it would probably be more desirable to use as a flux a limestone carrying 15 to 20 per cent of ferric oxide (10.5 to 14 per cent metallic iron) than one containing only 3 to 5 per cent ferric oxide, on account of the higher iron yield of the former limestone. Nevertheless, the ferruginous limestone would not commercially be styled an ore, while a bed carrying 25 per cent metallic iron (35.5 per cent ferric oxide) although in itself not rich enough to be used alone for the manufacture of iron would be conceded to be an "ore." In view of this commercial distinction, 20 per cent of metallic iron is considered as the minimum for an iron ore in this report.

The type of iron ore considered in this bulletin is restricted to that commonly known as "red" ore. Red ore is composed essentially of red hematite, or anhydrous ferric oxide, Fe_2O_3, together with a variety of impurities, such as silica, SiO_2, alumina, AL_2O_3, carbonate of lime, $CaCO_3$, carbonate of magnesia, $MgCO_3$, sulphur, S, phosphorus, P, and manganese, Mn. Occasionally a little hydrous iron oxide (limonite, or brown ore) is found mixed with the hematite, but it has resulted from the hydration of the hematite, or chemical combination of water with the ferric oxide, and does not occur in sufficient quantities to affect the composition of the ore to an important extent.

The distinguishing characteristic of the red ore is that it occurs in beds, or thin, lenticular masses of great linear extent, analogous to strata of shale, limestone, and sandstone, and it is interbedded with such rocks. One uncommon deposit is described in this report which is due to the concentration of residual red iron ore fragments and powder derived from bedded deposits. The origin of the bedded deposits will be dis-

cussed more fully under the description of the "Rockwood" ore, which will serve as typical of such deposits in Tennessee, and the detailed descriptions of the varieties of ore can more advantageously be presented in connection with notes on the several deposits, therefore such matter will be found in its appropriate section farther on in the text.

Ore-bearing formations.—Although many of the formations in the southern Appalachians contain small quantities of iron oxide scattered through the beds, only three formations in East Tennessee have been found to contain quantities sufficiently concentrated to warrant their being classed as red ore-bearing formations. Beginning with the lowest these formations are the Tellico sandstone, of Ordocivian age, the "Rockwood" formation, of Silurian age, and the upper or Mississippian part of the Grainger shale. Only the "Rockwood" formation contains ore of more than local importance.

In southern Tennessee between Chattanooga and the Georgia line the lower part of the "Rockwood," which contains thin seams of oolitic iron ore, locally developed, is according to Mr. E. O. Ulrich of Ordovician age. None of the ore seams in this locality that have been noted in the beds below the true Rockwood are thick enough to be mined except in a small way along the outcrop.

TELLICO IRON ORE.

Character.

Interbedded with the shale in the Tellico sandstone there are in a few localities thin seams or lenses of hematite of slight extent. Such ore as was noted during the present study varies from a ferruginous, calcareous sandstone to a rich, compact, material, composed mainly of iron oxide, and of relatively high specific gravity. Some of the ore is calcareous and contains many fossil remains. The richest beds range in thickness from a few inches to 18 inches, and much greater thicknesses of lean material have been measured. Where the Tellico sandstone has been disintegrated by weathering and the fragments of residual ore have been concentrated in basins on the surface of harder rocks, deposits of economic importance may be formed. Such a deposit, near Sweetwater, is described on pages 53 to 56, and several residual deposits located east of Knoxville are described on pages 62 to 71.

Distribution.

Although attention has been directed to the iron ore in the Tellico sandstone only in a few places, viz., east of Knoxville, between Holston and French Broad rivers; near Sweetwater, Monroe County, and near Riceville, McMinn County, there are probably other areas in which this

formation carries ore of similar character. The distribution of the Tellico sandstone is discussed on page 30.

RICEVILLE LOCALITY.

Location.—The ore noted near Riceville is included in the Tellico sandstone belt that extends northeast-southwest nearly parallel to the Southern Railway north of Hiwassee River and 1¾ to 2¼ miles east of the railway.

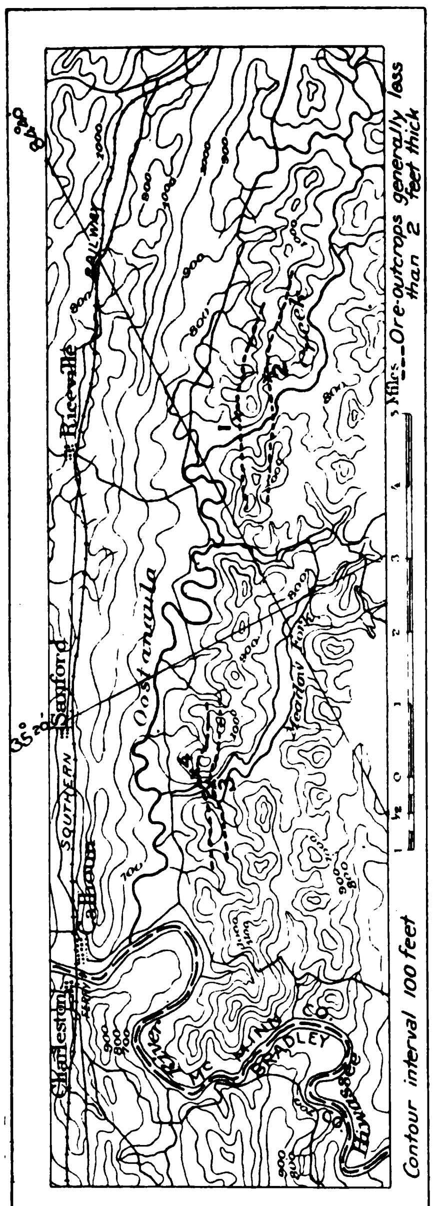

FIGURE 2.—Topographic map showing outcrops of iron ore beds in Tellico formation near Riceville. (Base from U. S. Topographic atlas sheets.)

Topographic and geologic relations.—The Tellico sandstone occupies a dissected ridge that rises 300 feet above Eastanaula Creek. This creek cuts through the ridge near Athens, flows along the east side of the ridge to a point nearly opposite Riceville, where it crosses to the west side and follows the base of the ridge nearly to Hiwassee River. The Tellico here consists of shale, sandstone, and thin beds of limestone, the shale predominating. The formation outcrops on the west limb of a syncline, and the dips are generally about 20° S. 75° to 80° E.

Description of ore beds.—There are at least two ferruginous horizons in the Tellico in this vicinity. The lower of the two observed lies apparently in the lower one-third of the formation and the upper one lies, as nearly as could be determined in driving across the formation, in the upper one-third. The lower ore horizon is exposed at a point about 2½ miles southeast of Riceville (indicated on the map, Fig. 2, by reference number 1). A bed of hard, compact, dark red ore, with a metallic luster, is exposed here. The thickness

averages about 9 inches and the range in thickness along a trench 100 feet or more in length measured 6 to 14 inches. The ore is laminated parallel to the bedding and splits easily. It is also jointed perpendicular to the bedding. The material is fossiliferous, and overlies a bed of fossiliferous, crystalline limestone, gray to chocolate in color. The dip of the bed is 20° S. 75° E. (See ore section Fig. 2a, and explanatory key, Fig. 14.)

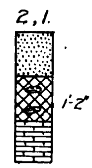

FIGURE 2a.—Graphic section of iron ore beds in Tellico formation near Riceville.

At this point the ore had been opened many years ago by trenching along the outcrop and stripping to a depth of 10 feet. Three carloads of ore thus obtained are reported to have been shipped in 1888 or 1889 to the Citico blast furnace at Chattanooga. At that time it cost per ton 75 cents to mine the ore; 75 cents to haul it to the railroad at Riceville, and 66⅔ cents freight charges to Citico, and the ore sold for $2.50 per ton, delivered. Judged by the appearance of samples and the analyses, given below, this ore is of excellent quality, but it is too thin, where observed, to be worked except by further stripping, and there is not much ore available for stripping. If the ore should increase to a workable thickness underground toward the southeast it might be advantageously worked by means of tunnels driven into the east slope of the ridge at a lower altitude. Considerable prospecting by drilling or tunnelling would be necessary in order to determine the thickness, however.

The lower seam of ore was noted also about 4 miles northeast of Calhoun on the hillside north of Meadow Fork. Reference No. 4, Fig. 2. At this point the ore is only about 6 inches thick and in places the color is quite dark, suggestive of the presence of manganese oxide. The dip here is 20° S. 80° E.

The upper horizon of ferruginous sediments noted in this vicinity displays great variation in character. At a point on the southeast slope of the ridge about 2¾ miles east-southeast of Riceville (No. 2, Fig. 2), a prospect pit disclosed about 3 feet of ore the full thickness of which could not be determined because it was not fully exposed. The position of the mass suggested that it might be a boulder that had become separated from its original bed. The ore is hard, compact, dark red in color, apparently contains much silica, and breaks into prismatic fragments that show slickensides. The dip of the beds here is 20°S. 80° E.

The upper iron horizon was noted also near Meadow Fork about 4 miles northeast of Calhoun. (Map reference No. 3, Fig. 2.) At this point there are 10 to 12 feet, and possibly more, of ferruginous sandstone. This sandstone is decomposed and rather soft where observed in a road cut. It lies in thin to medium thick beds, dipping 20° S. 80° E. The color is dark red to brown, but the rock here is apparently too low in iron oxide to be of value as an ore of iron at present. It is reported that several openings have been made on this seam at other places and that where the ore is hard and not decomposed it is of much better quality.

SWEETWATER LOCALITY.

Location.—This deposit of iron ore lies 1½ to 3½ miles northeast of Sweetwater, Tenn. It extends in a northeast-southwest direction, and throughout its whole extent is from one-half to three-fourths miles southeast of the line of the Chattanooga and Knoxville division of the Southern Railway. (See Fig. 3.)

Topographic and geologic relations.—The ore lies on the southeast side of the Sweetwater valley within 1 mile of the creek. It occupies a position not quite half way to the summit of the divide, and is between 75 and 150 feet above the level of Sweetwater Creek. The surface of the deposit is irregular, due to erosion, the thickest part of the deposit forming a gently rounded hill, while it is entirely cut through by a small branch that flows northwest into Sweetwater Creek.

The deposit overlies the Chickamauga limestone, and occupies a depression of irregular depth on the surface of the limestone. The prevailing dip of the rocks is about 15° toward the southeast. Southeastward from Sweetwater Creek the following rocks are passed over in an ascending scale: Knox dolomite, Chickamauga limestone (including Holston marble lentil) and Tellico sandstone. The latter formation is partly buried beneath the Knox dolomite along an overthrust fault on the southeast. These relations are shown in the structure section, Fig. 4.

The upper portion of the Knox dolomite is exposed between Sweetwater Creek and the overlying Chickamauga imestone to the southeast. There is considerable chert in the clay residual from the Knox, but where the rock beds are exposed they are generally grayish magnesian limestone. The Chickamauga is a mottled blue and buff, dense to partly crystalline, fossiliferous limestone. In places films of limonite appear on weathered ledges but are not found to extend far into the rock. The Holston marble in this area is a chocolate-colored to reddish-brown, medium coarsely crystalline stone, containing in some layers considerable ferric oxide. The Chickamauga (including the Holston marble lentil) is 500 to 700 feet thick.

The Tellico "sandstone," more appropriately termed "shale" in this locality, is principally a yellowish, sandy shale, with two or more seams of iron ore locally developed.

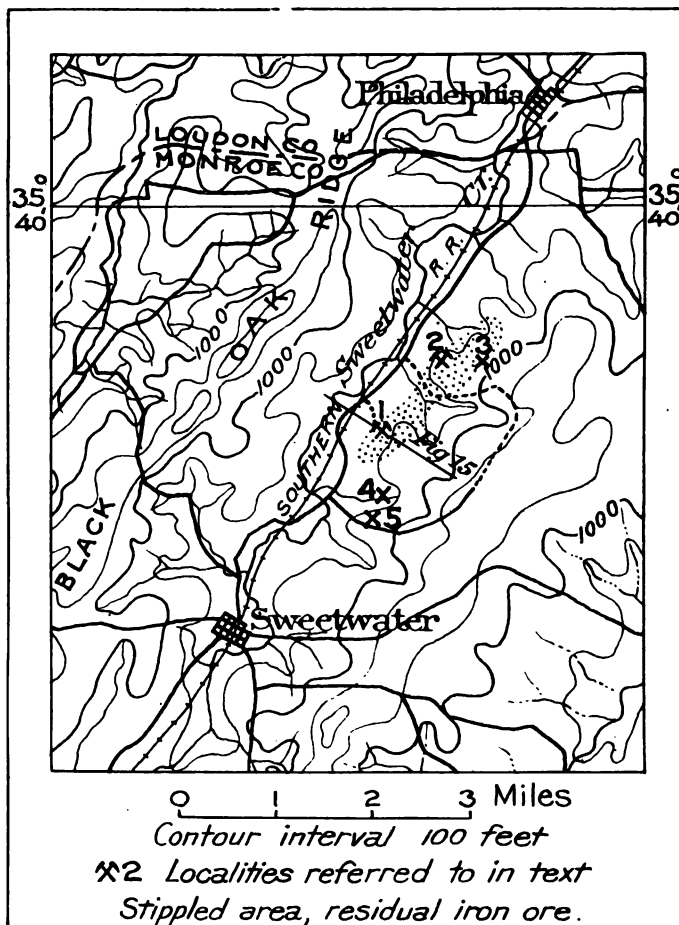

FIGURE 3.—Topographic map showing area in which residual iron ore is found near Sweetwater. (Base from U. S. Topographic atlas sheets.)

Character of the ore deposit.—If scattered lumps of iron and manganese oxides had not been plowed up by farmers in tilling the bright red soil of the locality, the possibility of the existence of ore in commercial quantity might never have been suspected. The abundance of these fragments in the fields and in gullies where they had been washed out of the soil led to the opening of some pits for the production of manganese ore a dozen years ago. After a few hundred tons of manganese ore

(psilomelane) in lump form had been shipped, work was abandoned for several years, but eventually a number of pits were sunk in the hope of finding more abundant supplies of manganese, and in these pits a peculiar dark reddish to bluish-black, soft, clay-like susbtance was found which proved on analysis to be rich in ferric oxide. One of these pits about 20 feet deep showed the following succession from the top downward: residual soil, sandy red clay, smooth fine-grained dark bluish-red clay, manganese oxide gravel, lumps of red iron oxide, black banded clay, and at the bottom fossiliferous ferruginous limestone dipping 8° to 10° southeast. The manganese ore carried 43 to 46 per cent metallic manganese and a little iron. Another pit showed at the top three to five feet of ferruginous soil with tough, hard, slickensided, angular thin fragments

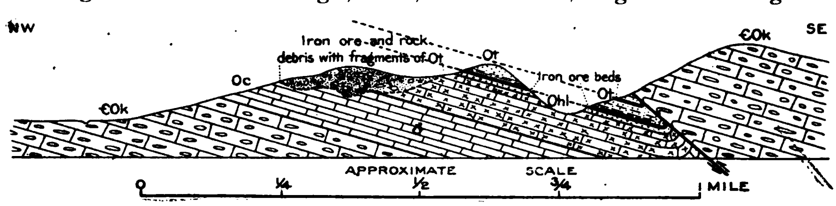

FIGURE 4.—Northwest-southeast structure section, near Sweetwater, showing position of residual iron ore and relation to Tellico ore beds and ferruginous Holston marble to the ore despoit.

€k, Knox dolomite. Oc, Chickamauga limestone.
Ohl, Holston marble. Ot, Tellico sandstone.

of iron ore ranging from ½ inch to 12 or 15 inches long, mixed with nodular lumps of manganese ore. Below this a bed of bluish red granular clay, 4 to 6 feet thick, lies like a blanket, following the contour of the hill. This material gives a bluish-red graphitic smut when rubbed between the fingers. The bed next below is about 6 feet thick. It is darker, but is of a lower specific gravity than the bluish material. In other pits this horizon is occupied by yellowish and black clay mixed. No rock was struck in several pits, but ferruginous limestone was noted at a lower level in the hillside toward the west. One pit which was started in on the limestone disclosed a very irregular rock surface with gravel iron ore lying in depressions in the limestone and covered by clay. Occasionally in the ore gravel and often among the surface ore fragments, waterworn pebbles of white sandstone and quartzite are found When moist all the clay is darker and less red than when dry.

The unique feature of this deposit so far as this region is concerned is that the dark bluish red and steel colored clay, and some of the reddish surface clay, really constitute an earthy iron ore. The dark variety is usually manganiferous, but some of the earthy material, although high in iron, contains only a little manganese. This locality was visited first in 1906. At that time mining was in progress and about 150 carloads of iron ore (more than 5,000 long tons) had been shipped, principally to blast furnaces in Chattanooga. The deposit was again visited in 1911

after considerable more mining had been done. The largest pit from which the material had been mined is near the top of the hill (Reference No. 1, Fig. 3), and had a face of about 25 feet and a diameter of about 100 feet. At the bottom of the pit a shaft had been sunk 40 feet, all in soft ore without reaching rock, but a well dug near the power-house, beginning at a level about 10 feet below the base of the pit, reached gray limestone within a depth of 40 feet, making a thickness of the loose sedimentary material of nearly 75 feet at that place. Near the entrance to the pit, which is reached by a passageway cut from the hillside, the soft ore and ore debris appears to occur in masses having rounded tops. (See plate VI.) Layers of manganese gravel follow the contour of the rounded masses. Some of the ore is sandy and shows limonite specks. Streaks of greasy pink hematite, with a graphitic feel, are found, and such material is called "iron fat" by the miners.

The hard ore fragments imbedded in the soft ore appear to have been broken from a bed in the Tellico sandstone that formerly extended over the area but which has been cut back eastward by erosion and disintegration. Many fragments show slickensides parallel to bedding and on joint planes. Pieces of ore 8 inches to 10 inches thick were noted, and masses 3 feet thick were reported to have been found. The fragments of hard ore strongly resemble the red ore occuring near Riceville, which is considered by Ulrich to be in the Tellico sandstone. The fragments of hard ore have not yielded many fossils, although one brachiopod and numerous crinoid stems were noted. The ore is also oolitic or granular in places. The hard fragments appear to have been derived from two or more beds; one rich in iron and the other lean and sandy, also a point of resemblance to the ore near Riceville. In the ferruginous earth forming the walls of a pit formerly worked for manganese ore (Reference No. 2, Fig. 3) about ¾ of a mile northeast of the pit first described, masses of sandy yellow shale and waterworn pebbles of white quartz sandstone, and angular pieces of fine-grained buff sandstone were found. Similar sandy shale occurs in places on the hills about one-fourth of a mile east of the old manganese pit in the area mapped as Tellico sandstone in the Loudon geologic folio. It overlies crystalline limestone belonging to the Holston marble lentil of the Chickamauga. Two pits were noted in this shale in which an ore seam had been cut. One pit (Ref. No. 3, Fig. 3) is in the lower part of the formation 15 to 25 feet above the highest observed outcrop of Holston marble, and about half a mile northeast of the "soft ore" mine. The other pit (Ref. No. 4, Fig. 3) is about three-fourths of a mile south of the ore mine. A thin bed, about 4 inches thick, is shown in the pit at point No. 5. It dips about 15° toward the southeast. This bedded ore is rich in iron, fossiliferous and granular, but has been leached so as to be spongy in places.

In the pit at point No. 4 the ore is evidently much thicker, although the pit was covered and the thickness could not be measured. Several tons of ore lie on the dump. The ore is very rich in iron. It is mostly hard, compact, and brittle, breaking into blocks with bright, slickensided faces. It is reported that this ranged from 18 inches to 3 feet in thickness, but pinched out to almost nothing in a few yards, and development was therefore discontinued. This pit is south of the limit given by Keith for the Tellico sandstone in this vicinity, but the shale shows plainly in the wagon road ½ mile farther south, where the ore also outcrops with a thickness of about 30 inches (Ref. No. 5, Fig. 3). The beds dip about 15° toward the southeast, and if projected northwest would lie above the present surface of the soft ore deposit.

Origin of the ore deposit.—The unconsolidated iron ore evidently has been derived in part from the ore beds in the Tellico sandstone and in part from the ferruginous material in the Holston marble and Chickamauga limestone. Some beds of the Holston marble contain 15 to 20 per cent of ferric oxide. When the calcite is leached out a large iron residue is left. This is well shown on the weathered edges of some beds of the marble, and by fragments from which the lime has been dissolved. In the Chickamauga limestone below the Holston marble lentil there are streaks of limonite from the thickness of a knife-blade to ¾ of an inch running irregularly through some beds. The topographic and geologic relations of these three iron-bearing formations strongly suggest that the deposit is residual from (a) the hematite beds in the Tellico sandstone that once extended over the area, (b) the ferric oxide in the Holston marble lentil of the Chickamauga limestone, and (c) the limonite streaks in other limestones of the Chickamauga. Surface water has assisted in the concentration, as is indicated by the rounded, waterworn pebbles of sandstone that have been carried into the deposit, and by the distribution of the nodules of manganese oxide in strata and pockets near the top of the mass of soft ore.

The most notable characteristic of the deposit is the large proportion of hematite present. Throughout the Appalachian Valley occur scattered deposits of limonite most of which are residual from the limestone beds that have been removed by solution, but nowhere has the writer seen another residual iron ore deposit in the south that was composed so largely of hematite. In this respect it resembles, on a small scale, some of the residual ore deposits of the iron ranges in Minnesota. It is not improbable that deposits similar to that at Sweetwater may be found at other places in East Tennessee where topographic and geologic conditions are both similar to those at Sweetwater.

Mining development.—Prior to 1907 mining was at first accomplished here by cutting down the bank with picks, carting away the stripping,

PLATE VI.

IRON ORE MINE THREE MILES NORTHEAST OF SWEETWATER, TENN.
Shows rounded mass of dark soft ore overlain by reddish clay.
Photo by E. F. Burchard.

and moving the raw ore in wagons to the siding on the Southern Railway about ¾ of a mile distant, where it was dumped into cars and shipped to Chattanooga. Some time within the next four years attempts were made to briquette the ore, and a second-hand stiff-mud brick-molding machine was erected. The soft ore was trammed from the pit on small cars, mixed with a little water, and about 100,000 bricks were then built up in kilns and burned just enough to harden them sufficiently to enable them to stand handling and transportation, the moisture being mostly driven off by the process. The ore so treated is reported to have cost $1.26 per ton, and to have been successfully used in the briquetted form by certain blast furnaces. It was not possible to maintain a sufficiently large output from this plant and its use was discontinued, but the results of the briquetting of the ore demonstrated that the quality and physical condition of the ore could be much improved through some method of concentration and conversion to a more solid state. Consequently preparations were made first to develop a large output of the ore, and next to install an ore-sintering plant.

In October, 1912, a 20-ton steam shovel was started stripping cover and digging ore. The ore was loaded into mine dump cars which carried the ore about 900 feet and dumped it into wagons in which it was carried the remaining ⅝ of a mile to the railroad. Nearly 8,000 long tons of ore are reported to have been shipped to blast furnaces in 1912. Average analyses are reported to have shown a little more than 40 per cent metallic iron, and between 2 and 3 per cent manganese. It is reported that another steam shovel is soon to be installed, and that the construction of 1,200 feet of new siding from the Southern Railway to the site of the sintering plant is underway (January, 1913). It is reported that the sintering plant is to be built by the American Ore Reclamation Company and will comprise four Dwight-Lloyd sintering machines. This plant is planned to produce 400 tons of sintered ore daily, and it is considered that this sinter, which is cellular in structure, should require much less coke than is required to reduce natural iron ores.

Prior to installing the steam shovel 200 acres of this ore land were surveyed and platted, 40 test holes, 15 to 80 feet deep, were sunk 100 to 200 feet apart, cross sections were drawn, and analyses were made of samples of the ore taken every 5 feet from the test holes, but none of the results of this work could be obtained for inspection by the Survey.

According to reports of recent operations the costs for mining by steam shovel, hauling, and loading the ore on railroad cars were reduced to a very much lower average than before the steam shovel was installed, and it is expected that these costs will be still further lowered when a tramway entirely supplants hauling by team.

A good market is assured for several times the proposed daily output of this mine and sintering plant, so that if the ore exists in sufficient quantity and the beneficiation of the ore proves successful the future exploitation of this ore deposit should be very promising.

Analyses of iron ore from near Riceville and Sweetwater.

Locality.	Authority.[1]	Fe	SiO_2	Al_2O_3	CaO	MgO	Mn	P	S	H_2O
Riceville:										
Soft ore—										
McMinn-Thomas bank...	B	56.65	9.67	......	......	......	......	0.52	0.09	7.85
McCamey..............	B	60.21	13.82	......	......	......	......	0.72	0.09	1.02
Dodson Ridge...........	B	60.03	13.34	......	......	......	......	0.13	0.12	1.32
Carruths Place..........	B	56.58	18.05	......	......	......	......	0.65	......	1.10
Meadow Park and Dodson's	B	43.32	32.18	......	......	......	......	......	......	......
Sweetwater:										
Unconsolidated ore........	O	46.90	20.16[2]		......	......	2.12	......	......	......
				7.41						
		32.30	44.92	5.61	......	......	......	......	......	......
		45.18	16.27	......	......	......	......	......	......	......
		43.91	23.30	......	......	......	......	......	......	......
Do	E	52.32	8.52	7.73	......	......	2.50	1.71	......	......
Do	Ch	47.84	16.22[2]	11.41	......	......	2.78	0.51	......	......
Do	Ch	50.75	17.20[1]	10.16	......	......	......	......	......	......
Do	Ch	59.20	5.30	......	......	......	......	0.22	......	......
Do	Ch	33.86	43.80[2]	6.10	......	......	2.43	0.435	......	......
Ferruginous limestone......	Ch	8.71	4.10[2]		76.90	......	......	......	......	......
Do	C	12.11	6.68[2]		......	......	......	......	......	......
Heiskell Tract Prospect samples:	L	46.50	22.56[2]		......	......	1.18	......	......	......
	L	11.10	68.56[2]	......	......	......	......	......	......	......
	L	39.90	28.44[2]	......	......	......	......	......	......	......
	L	15.50	61.94[2]		......	......	......	......	......	......
Unconsolidated ore........	L	29.90	37.52[2]		......	......	......	......	......	......
	L	41.30	22.78[2]		......	......	......	......	......	......
	L	46.90	......	7.41	......	......	2.12	......	......	......
Heiskell Tract............	L	40.90	23.98[2]		......	......	......	0.22	......	......
	L	35.90	30.36[2]		......	......	......	......	......	......
	L	53.20	7.32[2]		......	......	......	0.46	......	......

[1]Authorities: B:—W. M. Bowron; O:—owners; E:—Embree Iron Co.; Ch:—Chattanooga Iron & Coal Co.; C:—Citico Blast Furnace Co.; L:—La Follette Iron & Coal Co.

[2]Insoluble.

TUCKAHOE DISTRICT.

Historical note.—This bulletin was planned to describe only the red iron ores of East Tennessee, and no work was done by the writer on the brown ores, or limonites, of the State during this investigation. In view of the interest that is at present being taken in the iron ore deposits lying between Holston and French Broad rivers in Knox and Jefferson counties east of Knoxville, and in view of the fact that these deposits are somewhat similar in origin and geologic relations to the deposit near Sweetwater, described above, it has been decided to present here the essential points previously published by Professors C. H. Gordon and R. P. Jarvis, of the University on Tennessee, on the Iron Ore Deposits of the Tuckahoe District. The complete paper was published in the December, 1912, issue of The Resources of Tennessee, by the Tennessee Geological Survey, pages 457 to 478. According to the following description the ore consists of both hematite and limonite, as is the case near

Sweetwater, although near that place hematite predominates. In the Tuckahoe district the limonite has probably been formed, for the most part, through the hydration of hematite, and similar results have been observed with regard to some of the soft "Rockwood" ore near Chamberlain. Since this type of brown ore is directly derived from bedded deposits of the normal red-ore type it is much more closely allied to the bedded red ore than it is to the typical Appalachian Valley brown ores, and should logically be grouped with and described with the bedded red ores.

The following quotations on this subject are taken from the report by Professors Gordon and Jarvis, mentioned above:

"The occurrence of deposits of iron ore in the region between the Holston and French Broad Rivers has been known for many years. The earliest mention made of these ores of which we have record, was in an address at a public meeting at Knoxville in 1869, by Gen. J. T. Wilder[1], who made a study of the deposits a short time before. No action was taken at this time, however, toward mining the ores.

At one time efforts were made in a small way to work the ores, a forge having been erected on Tuckahoe Creek for the purpose, but we have no information as to the results of this enterprise nor of the parties engaged in it. None of the early writers on the geology of Tennessee, Troost, Curry or Safford, so far as we can learn, made mention of these deposits, though the latter recognizes the ferruginous character of the formation in which they occur.

About twenty years ago these deposits were extensively prospected by a company composed of Chattanooga men, who obtained possession of them in part by purchase of the land and in part by the purchase of the mineral rights. This company still retains control of the deposits, though as yet no effort has been made to develop them.

The first reference in print we have of these deposits is by Arthur Keith, who wrote as follows:[2] "On Tuckahoe Creek east of Knoxville, brown hematite results from the decomposition and accumulation of the ferruginous matter in the Tellico sandstone. The ores have been extensively prospected and are of good quality. They are not, however, of great body, although their surface indications are extensive; no mining of importance has been done. Many other outcrops of red and brown hematite occur in the form of veins and irregular deposits in the Tellico sandstone, but they are not of large quantity."

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[1]Personal letter to writer, dated October 25, 1912.

[2]Knoxville folio, U. S. Geological Survey, 1895, p. 6.

[These deposits are mentioned by J. B. Killebrew, in his report on the Iron and Coal of Tennessee, published by the Tennessee Commission of Agriculture and Mines, 1881.—E. F. B.]

Location.—"The iron deposits are located in the district comprising portions ot Knox and Jefferson counties lying between the Holston and French Broad Rivers, about nine miles east of Knoxville. All the known outcrops of the ore occur in an area approximately four miles wide and fourteen miles long in an east-west direction.

The drainage of the district is effected by small tributaries of the French Broad River, the chief of which is Tuckahoe Creek. The nearest railroad point is Straw Plains on the Southern Railway, about four miles north of Thorngrove, and approximately eight miles distant from the most easterly and the most westerly openings."

Geology.—"The rocks of the region belong to the lower Paleozoic era, including formations of the Cambrian, Ordovician, and Silurian periods. The outcrops of the beds occur in a series of belts extending from northeast to southwest as a result of the planing off by erosion of a series toward the northwest. In places a rupture of the fold has taken place along the northwest side with an overthrust of the beds in that direction.

* * * * * * * * * * * * *

Toward the southeast the sedimentary area is bordered by older crystalline rocks, the decay of which has furnished the material which makes up the sandstones and shales of the area. The existence in the Appalachian region in early Paleozoic time of long, narrow barriers separating equally long narrow troughs or basins which received unlike sediments and contained unlike faunas was early recognized by Safford* and noted by other geologists since."

In the following table by Gordon and Jarvis an outline is given of the geological formations of the central part of Tennessee Valley, the lowest rocks being the oldest. The general character of the formations is also indicated in the outline. The nomenclature and classification do not agree in all particulars with those used by the United States Geological Survey in the same area.

Geological formations of the central part of the Tennessee Valley.

System.	Stage.		Formation.
Silurian	Clinton		Rockwood.—Shale, sandstone and iron ore. Clinch.—Sandstone.
Ordovician	Chickamauga		Bays formation.—Limestone and sandstone. Sevier formation. — Shale, sandstone and limestone. Tellico formation. — (Moccasin limestone), calcareous [and ferruginous] sandstone and shale. Athens formation.—Shale. Holston marbles.—Pink and variegated marble. Lenoir limestone.—Knotty limestone. Mosheim limestone—Compact limestone.
	Knox		Upper Knox dolomite. Copper Ridge chert (Ulrich). Lower Knox dolomite.
Cambrian	Middleand Upper Cam.	Conasauga	Nolachucky shale. Maryville limestone. Rogersville shale. Rutledge limestone.
		Rome	Rome sandstone and shale.—Watauga shale.
	Lower Cambrian		Chilhowee, etc.

*Glenn, L. C., Resources of Tennessee, May, 1912, Vol. II, No. 5, p. 216.

Only the description of the Tellico sandstone, which is the source of the iron ore deposits in this district will be quoted in detail here.

"*Tellico sandstone.*—Overlying the Holston marble, and where this is absent, resting upon the Lenoir limestones are beds of hard, gray, dark-bluish, calcareous sandstones and sandy shales closely interbedded. By increase in the lime constituents the sandstones grade locally into limestones which usually contain a considerable amount of sand. The limestone phases of the rock are highly fossiliferous, the comminuted fragments of crinoids and shells making up much of the rock. This formation contains a large amount of iron because of which it was named by Safford the "Iron-Limestone." By the solution of the lime carbonate it weathers into a porous, dark-red or brown, sandy mass, the sandy skeleton of which often remains hard enough to cause lines of red knobs 100 to 200 feet high, which constitute a conspicuous topographic feature of the region i which the formation outcrops.

Toward the northwest by the increase in the calcareous constituents the formation changes into red limestones and shales which there receive the name of the Moccasin limestone formation. In the area between the Holston and French Broad rivers the Tellico formation appears in two main belts with some minor isolated areas, as a result of the planing off by erosion of the folds of the strata. The easternmost of these areas and the one in which most of the iron deposits occur, crosses French Broad River east of Riverdale and extends thence northeast to a point about two miles beyond Cynthiana where it makes a sharp bend to the southwest, coming to an end by faulting a few miles beyond. This arrangement of the strata is caused by a synclinal fold. The Vance prospect is on the north limb of an anticline which brings the Knox dolomite to the surface in the intervening area. Another belt of the Tellico lies along the south side of the Holston, coming to an end by faulting about three miles east of Straw Plains. Toward the southwest, south of Knoxville, these belts merge into one broad belt of red knobs which constitute a conspicuous feature of the valley in that region. In addition there are several small areas where owing to minor folds the Tellico appears within the area of the Sevier shales. The Tellico formation, which east of Straw Plains has a thickness of 300 to 400 feet, thickens quite rapidly towards the south and west to 800 to 900 feet.

In the vicinity of Knoxville the rock has been quarried for curb stones and road making. Locally ripple marks are well developed indicating deposition in shallow water and mud flat areas. Horizontally the flaggy sandstones grade into limestones and shales.

Analyses of the rock from the top of the bluff on the south side of the river give the following results:

*Analyses of limestone in the Tellico formation.**

	No. 1	No. 2
Moisture	0.30	0.35
Silica	6.93	1.68
Fe and Al oxides	3.34	11.72
CaO	47.80	46.08
MgO	1.80	1.75
CO_2	39.45	38.05
Sulphur	0.05	0.05

The highly ferruginous character of bed No. 2 has also lower content of silica and is of interest in connection with the origin of the iron ores in the Tuckahoe region.

* * * * * * * * *

DESCRIPTION OF THE ORES AND PROSPECTS.

The iron ores of the Tuckahoe District are comprised within a belt approximately 14 miles long and four miles wide lying between the Holston and French Broad rivers. The southern extremity of the belt lies approximately four miles northeast of the junction of the two rivers, and extends in a general northeast direction to McCampbell's Knob, situated seven miles southeast of Straw Plains. The southwest extremity of the belt is about nine miles northeast of Knoxville. The iron-bearing zone as thus defined, is included within the three counties of Knox, Sevier and Jefferson.

The district is readily accessible by good pike roads from the station of Straw Plains, 16 miles northeast of Knoxville on the Bristol and Knoxville division of the Southern Railway. The southwest extremity can be reached from Knoxville over the Dandridge pike, and with the completion of the branch line of the Southern Railway to the marble quarries between the forks of the Holston and French Broad rivers, the deposits in part or brought within a distance of four to five miles of rail transportation. Owing to the close proximity of the rivers to the entire belt, water transportation is within easy reach.

The formation carrying the iron-bearing beds in this district is known as the Tellico sandstone, a gray and bluish-gray, calcareous, and ferruginous sandstone ranging from 100 to 300 feet thick, of Silurian age. The formation derives its name from Tellico Plains in Monroe County, where it is extensively developed. The outcrop of this formation is usually defined by a well marked chain of knobs. The iron-bearing member within this formation consists of a ferruginous limestone, but often siliceous in part, which has been thrown into multiple folds, giving rise to a series of parallel veins of beds. All members of the Tellico formation weather rapidly, and owing to this fact, and the relatively high iron content in certain beds, these have formed under favorable conditions, considerable accumulations of a very good grade of iron ore.

The analogy between the iron ores in the Tellico and those found in the Rockwood formation (the Clinton iron ore horizon in Tennessee) is remarkable. This similarity holds not only in the association of the iron beds with the inclosing rocks, shales and limestones in both cases, but also with reference to the chemical composition of the ores, and their physical condition. But the analogy apparently no longer holds when we trace the iron ore beds of the Tellico beneath the surface. In the case of the Tellico formation it has been found that the concentration of the iron, due to the action of surface agencies in leaching the more soluble lime carbonate of the iron-bearing limestone, and converting the primary iron carbonate into iron oxide, has not progressed to any great depth. Practically all the openings and prospects made on these veins have either been near the crests of the ridges or knobs, or on the steep slopes of narrow hollows and ravines, and usually upon the side of the hill having a southern exposure.

An inspection of the accompanying map (Fig. 5) shows there are three roughly parallel belts (of Tellico sandstone), of which the central belt is the longest and the most extensively exploited. This repetition of belts is due, of course, to sharp folding and faulting; and, as explained above, the occurrence of three or more parallel beds or veins, is doubtless the result of multiple folds. The multiple fold structure is very prettily shown at Moore's Knob. Generally the iron veins have a steep dip to the southeast, with the strike conformable with the outcrop of the Tellico formation.

Four localities were examined, viz.:

1. Johnson's Knob. Prospects on the farm belonging to G. W. S. Johnson.

2. Maurer's place, or farm now owned by Samuel Vance.

3. Moore's Knob, situated close to a farm owned by Jesse Campbell, and on a farm owned by J. R. Moore.

4. McCampbell's Knob. Prospects situated on a farm belonging to the McCampbell heirs, and also on other contiguous farms owned by Joshua Cates, Charles Snyder, *et al.*

From the principal prospects at each of these localities, samples were taken, and where accessible, measurements of the ore bodies were made. Beginning with the southwestern extremity of the district, and going northeastward, we have:

Prospects on Johnson's Knob. The prospects on this knob are on the farm of G. W. S. Johnson, approximately six miles east of the forks of the Holston and French Broad rivers, in Knox County. All openings are on the south and southwestern slopes of the knob, and within 300 or 400 feet of its crest. The development on this tract consists of two pros-

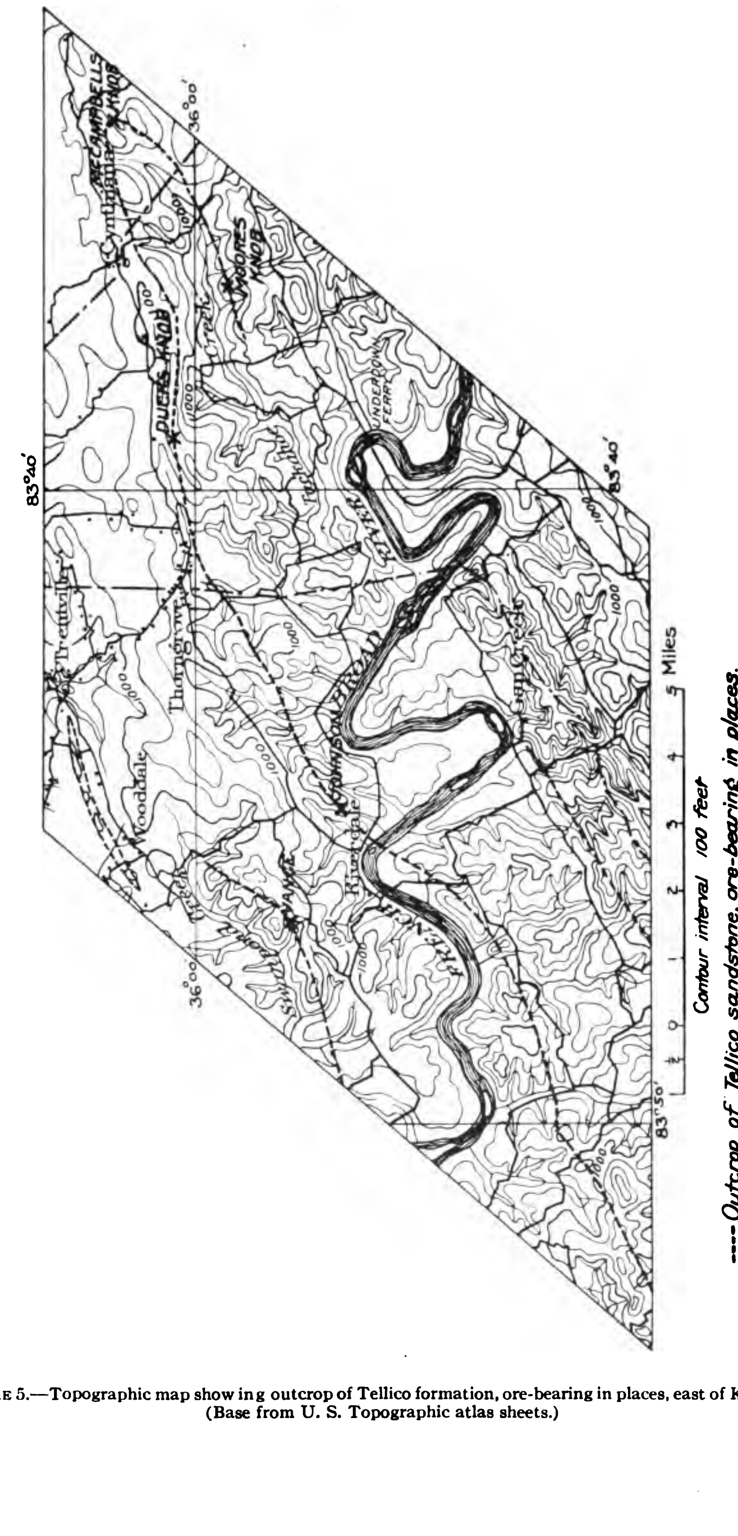


FIGURE 5.—Topographic map show ing outcrop of Tellico formation, ore-bearing in places, east of Knoxville (Base from U. S. Topographic atlas sheets.)

pect shafts, an open cut, and the showing of ore in the cellar of Mr. Johnson's house. There are four parallel veins, with steep dips to the southeast, which are designated as follows:

1.—North vein: This occurs close to the contact between the Holston marble and Tellico sandstone. It consists of a narrow vein of hard hematite 18 inches thick, right on the crest of the ridge, 300 feet north of Mr. Johnson's house, and analyzed as shown in No. 1 table.[1]

2.—No. 2 vein, south: This is developed by a shaft (filled at time of visit) approximately 30 feet from No. 1 vein. The width sampled was 10 feet, and the sample was taken one foot from the top of the ground. It analyzed as shown in No. 2 of the table. The shaft was originally less than 10 feet deep, and judging from the appearance of material on the dump, and the analysis, the ore is lean and of little value.

3.—No. 3 vein, south: This is developed by a shaft said to have been 30 feet deep at the time it was sunk (now filled to within 20 feet of the surface), and the exposure of ore in the cellar under Mr. Johnson's house. The shaft is situated about 300 feet northeast of the house. The ore exposed in both places is soft hematite. A sample cut across the vein, two feet below the top of the shaft, for a width of four feet, analyzed as shown in No. 3 of the table.

The vein dips to the southeast, and in sinking the shaft vertically it passed into the foot-wall, but a sample selected from the surface of the dump gave the analysis as shown in 6.

The sample taken from Mr. Johnson's house was of select material, and the width was not definitely ascertained, but probably 12 to 14 feet would cover it, and which analyzed as shown in No. 4, table. Upon a hasty inspection of a sample of ore of this character its true value is likely to be underrated, as there is not much in the soft, pulverulent and light material to suggest a high percentage of iron.

4.—No. 4 vein, south: This is approximately 350 feet south of No. 3. The development consists of an open cut across the vein, four to five feet in depth. The vein dips southeast at a high angle. The width sampled was 12 feet, the analysis of which is shown in No 5. The sample was cut at a depth of three feet from the surface. The character of the ore is brown hematite, or limonite, and practically identical with the sample taken in No. 2 vein. The continuity of neither of these veins along the surface has been demonstrated, and the results of the analyses do not promise well. There is left, therefore, the No. 3 vein as the only prospect that has any possibility of developing into something of value. The values in this vein are high enough, and the property could be made accessible to rail transportation, provided a deposit of sufficient size could be found. It is the opinion of the writer that while conditions have been

[1]For analyses herein mentioned see table on page 73.

favorable for a deeper average alteration of the primary iron-bearing member, possibly to a depth of 50 or more feet, yet at moderate depths it will be found that the iron content diminishes until the grade becomes too low to be of value.

Prospect on Maurer's place, Vance farm.—The prospects on the Samuel Vance farm consist of an outcrop across the road and through the field back of Mr. Vance's house, and a single prospect cut 50 feet above the road. This deposit, as opened in the cut, consists of a vein 7.5 feet wide, dipping steeply northwest. As shown on the map, this vein occurs in the most northern belt. It has not been prospected along its strike to the northeast, but owing to the fault about one mile northeast of the prospect, the vein is cut off. This vein is made up of alternate bands of lean and rich ores, the thickest being two feet and eight inches. This, with a band on the foot- and hanging-well, each one foot, gives a total thickness of nearly five feet of high grade ore, which analyzed as shown in No. 7 of the table. The two lean seams, of about equal thickness, lie next to the ore seams on the foot- and hanging-walls. An average sample cut across the entire vein analyzed as shown in No. 8 of the table.

The ore is a typical soft red hematite, breaking into blocks, and of very suitable grade and character This vein has scarcely been developed to a depth of six feet, but owing to the fact that the cut where the vein has been exposed is not more than 30 feet above the drainage level of the adjacent lands, it is quite likely that even before this depth is reached the iron content seriously diminishes.

Prospect on Moore's Knob.—The prospects in this locality are located on farms belonging to J. R. Moore, *et al.*, between six and seven miles southwest of Straw Plains, near the southern extremity of the south belt. Prospecting in this locality has been carried on in two places. The one farthest south is about a quarter of a mile southwest of Mr. Jesse Campbell's house, and the other, two-thirds of a mile to the northeast of this. The prospects on the south all appear to have been made upon a single bed or vein which has been thrown into folds so as to simulate five or six different veins; and this locality serves perhaps better than any other to illustrate the structural features of these iron ore beds. All the prospects are on the northeast side of the wagon road, and consist of open cuts, short tunnels, and one or two shallow winzes in some of the tunnels. It was not possible in the time to sample thoroughly all the openings here, or to make a close examination into the results of the deeper underground work. None of the tunnels exceed 50 feet in length, and the greatest depth of any of the workings beneath the surface was not more than 25 feet. Two diamond-drill holes were put down to a depth of 200 and 213 feet, respectively. The result of this drill prospect work was not learned, but from the structure plainly revealed in

the open cut, prospects not more than 75 feet distance, it appears that the work was unnecessary, since the open cut prospecting had been done before drill work was commenced. The following sketch shows the relation of the bed at this place:

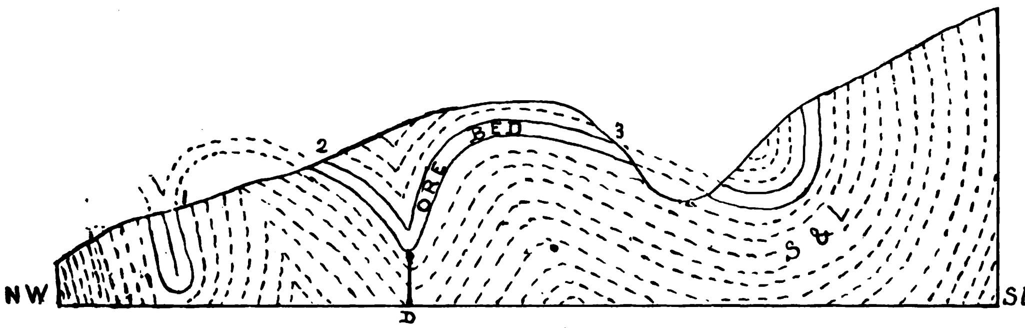


FIGURE 6.—Northeast-southwest section of Moore's Knob.
S and L, shales and limestones.
1, 2, and 3, tunnels Nos. 1, 2, and 3.
D, diamond drill hole.

Beginning with the prospects on the northwest and going southeastward the following prospects were noted:

1. This consists of tunnel No. 1, an open cut 50 to 60 feet long, with a short cross cut, and a winze driven and sunk into the foot-wall. The tunnel follows a soft, decomposed streak of hematite, which was sampled in an open cut made on the same vein about 50 feet above and beyond the tunnel. The vein where sampled measured 13 feet in width, and dipped 80 degrees to the northwest, and analyzed as shown in No. 9 of the table. The sample was taken from an average depth of four feet from the surface.

2. Tunnel No. 2 is 140 feet southeast of No. 1. The development consists of an open cut 15 feet long, at the end of which is a short tunnel seven feet long. The dip is only 28 degrees, and to the southeast. The weather ng has not progressed to any considerable depth, and the ore is hard, limey and low grade, as the analysis shows in No. 10 of the table. The width sampled was 4.5 feet.

3. Tunnel No. 3 is 100 feet southeast of No. 2. The prospect consists of an open cut 20 feet long and a tunnel extending 15 feet beyond. The ore is soft for a few feet from the surface, but rapidly changes into hard ore, identical with that from No. 2 tunnel within a few feet from surface. The total depth under cover at the end of the tunnel is no more than 15 feet. The vein is much contorted, and the widths are easily ascertained. The sample was taken about seven feet beyond the end of the open cut, and represents a thickness of seven feet, at which point there was still considerable soft ore. The analysis is shown in No. 11 of the table.

4. Tunnel No. 4 is approximately 200 feet southeast of tunnel No. 3. An open cut runs for a distance of 25 feet, and a tunnel is continued some 40 feet beyond. Both follow the soft hematite, but eight feet beyond the cut, the rock, for a short distance, becomes hard. Through the remaining distance, the tunnel is driven in softer rock, which is a ferruginous shale, more or less decomposed on the foot-wall side. The vein at this point has a dip of 68 degrees to the southeast. No samples were taken from this prospect.

5. There is a small open cut between Nos. 2 and 3. The tunnels are 30 feet above the wagon road. In this cut a small syncline is exposed in which the iron-bearing limestone has been folded on itself, thereby doubling the thickness of the vein, and probably explaining the variations noted in the widths of the veins as exposed in different sections. The following sketch illustrates the structure:

A sample selected from this cut analyzed as shown in No. 12 of the table. This sample was cut across a width of six feet, and at a depth of five feet from the surface. Very little change has taken place in the original ferruginous limestone, as indicated by the analysis.

The other prospects located about two-thirds of a mile northeast, included within Moore's Knob, were as follows:

1. A wide, open cut, and tunnel near the bottom of the hollow, where a steeply dipping series of ferruginous limestone, shales, *etc.*, showing various stages of weathering, had been exposed. The total width that could properly be termed iron-bearing measured 28 feet, with a dip of 80 degrees southeast. The tunnel had been driven for some distance in the soft iron ore on the foot-wall side. The writer was unable to examine the tunnel, nor was a sample taken from the rich decomposed surface ores; but a sample was cut from the balance of the exposed vein in the open cut across a width of 20 feet, and analyzed as shown in 13.

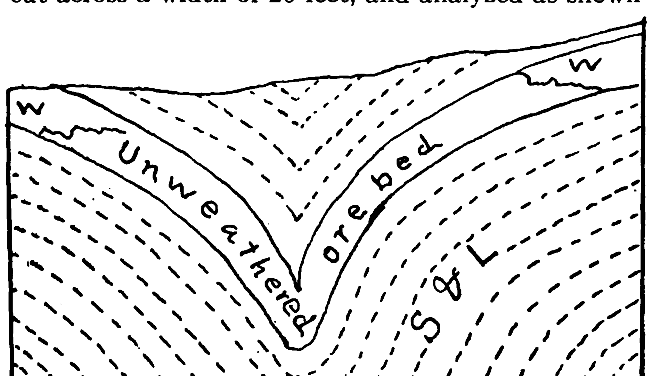


FIGURE 7.—Shows the structure in opening No. 5, Moore's Knob prospect.
S and L, shale and limestone.
WW, weathered portions of ore bed.

2. This same vein had been crosscut its entire distance further up the hill, about 150 feet northeast of No. 1. The total width was 25 feet, and a sample cut across the entire width, three feet below the surface, the analysis of which is shown in No. 14 of the table. In this section the writer was unable to distinguish any beds that appeared to be much richer in iron than the others. This section is interesting as showing the rapid downward rate with which the lime increases, and with the increase in lime the corresponding decrease in iron, as will be seen by comparing the two analyses on the same vein. It is also very significant as indicating the difficulties of estimating, even within very limited areas, the possible tonnage and iron content, owing chiefly to the great irregularity in depth of weathering, and consequent enrichment in iron.

3. This is an open cut 250 feet southeast of Nos. 1 and 2. Here the vein is much flattened, as noted in the other section to the southwest, and has a width of nine feet. The vein is much weathered in places. A sample cut across the vein analyzed as shown in No. 15 of the table.

4. This consists of a tunnel and open cut, 125 feet southeast of No. 3. Here the vein, evidently the same as exposed in No. 3, dips very steeply southeast. The crosscut and tunnel are together about 30 feet long. A crosscut has been driven into the foot-wall about 12 feet, running southeast. A sample taken along the sides of this cross-cut, covering a width of 18 feet, analyzed as shown in No. 16 of the table. This sample is not more than 10 feet beneath the surface and shows the effect of weathering.

Prospects on McCampbell's Knob and vicinity.—This locality, as shown on the map, is located eight miles southeast of Straw Plains, and in an air line about six miles from New Market, the nearest railway points. These deposits represent the northeast extermity of the Tuckahoe belt. Beyond this, to the northeast, the iron-bearing measures are cut off by faults and disappear.

Some of the prospecting in this locality was done twenty or more years ago, but most of that herein described is recent. The following veins and prospects were noted, beginning with the most northerly vein:

1. North or No. 1 vein, follows the crest of the ridge for a distance of a mile. Where it was sampled near its northeast extremity, in an old open cut it showed a dip of 60 degrees southeast. A sample covering 10 feet, cut from a depth of four feet from the surface, analyzed as shown in No. 17 of the table.

About 1,500 feet southwest along the strike of this vein, another open cut has been made, exposing the vein for a width of 10 feet. A sample was cut across the vein at a depth of seven feet from the surface, which gave the analysis shown in No. 18 of the table. This same vein is again exposed approximately 200 feet southward from the above cut, on land belonging to Joshua Cates. A shaft was sunk on the vein to a depth of

40 feet. The writer could not examine the bottom of the shaft, but from an examination of the material exposed on the dump it has evidently passed through the zone of weathering, and into the lean original ferruginous limestones of the Tellico. A sample of this unaltered limestone from the dump analyzed as shown in No. 19 of the table. A sample taken of the soft material from this dump analyzed as shown in No. 20 of the table. This material had evidently been taken out during the early stages of shaft sinking and represents therefore the richer and weathered portions of the vein.

2. Vein No. 2, south, is 200 feet southwest of vein No. 1. The dip and strike are the same as No. 1. A sample from an open cut across a width of 6.5 feet, gave the analysis shown in No. 21 of the table. Some 300 feet below this cut, near the bottom of a hollow, this same vein is prospected by a tunnel 50 feet long. This tunnel follows a soft, decomposed streak of hematite for a distance of about 25 feet, where the bed becomes hard, owing to the increased lime content. The course is then changed slightly, breaking into the hanging-wall, where it is softer digging, and in which it is continued for another 25 feet. A sample taken across the breast of the tunnel, with a width of five feet, analyzed as shown in No. 22 of the table. Another sample taken across the face of the vein where the tunnel leaves it and breaks into the hanging-wall, analyzed as shown in No. 23 of the table. This sample can hardly be called a representative one, since it contains both soft and hard ore. This prospect is interesting and instructive, showing the sudden change from soft ore of high grade to the much leaner, hard and calcareous ores of the primary iron limestone.

3. Vein No. 3, south, is 35 feet southeast of the first sample from No. 2 vein. The width sampled was five feet. The dip and strike are the same as No. 2. The sample analyzed as shown in No. 24 of the table.

4. Vein No. 4, south, is approximately 100 feet southeast of No. 3. Here an open cut exposes iron-bearing material, having a width of 19 feet, of which four feet is a lean parting, which was not included in the sample. The analysis is shown in No. 25 of the table. The sample was cut at a depth of three feet from the surface.

5. Vein No. 5, south, is 200 feet southeast of No. 4. This is a small open cut on the Bartlett place. The dip and strike are the same as Nos. 1 and 2. The cut was shallow and the sample taken from a depth of two feet from the surface, and across a width of six feet, analyzed as shown in No. 26 of the table. This weathered and enriched part evidently does not extend to any great depth, since on the opposite side of the cut, six or seven feet distant, hard parts of the vein could be seen.

This vein, as shown on the map, extends to the southwest, a distance of a mile or more beyond the above prospect, and has been opened in sev-

eral places on the Charles Snyder farm. Veins Nos. 2, 3 and 4 disappear as they are traced to the southwest. Thoroughly weathered samples of ore from prospects on the Snyder farm, near the house, analyzed as shown in No. 27 of the table. The width sampled was 7.5 feet, and the depth below the surface was four feet. This prospect has a southern exposure, and accounts for its deeper and more thorough weathering.

Along the course of this same vein, 600 feet southwest, it has been opened in a shallow open cut where the processes of weathering are well shown. Here the iron-bearing member consists of a massive ferruginous limestone 14 to 16 feet thick, dipping 35 degrees southeast. Where the cut has been made, it is about 40 feet above the level of the stream bed. The weathered and decayed portions of this limestone, which was very irregular, but in no case extending to a depth of more than eight feet from the surface, gave the analysis shown in No. 28 of the table, while in the same cut, but from the unweathered and unaltered parts of the limestone, the sample analyzed as shown in No. 29 of the table.

At Buck's Knob, situated about four miles southwest of McCampbell's Knob, some prospecting has been done, but these prospects were not visited.

ORIGIN OF THE ORES.

The evidence that the richness of the iron ores of the Tuckahoe district is due to the leaching out by surface agencies of the more soluble lime carbonate of the iron-bearing limestones of the Tellico formation and the concentration of the iron in the surficial portions is ample and conclusive. As already noted, the exposures are in practically all cases at the tops of knobs and ridges or in narrow hollows and ravines where erosion has not been sufficient to remove all the products of decomposition. The extent of the deposits is therefore proportional to the depth to which the work of the weather has progressed and the amount of erosion. According to locality, the leaching and the consequent concentration of the iron constituents extends to depths of from 1 or 2 to 40 or 50 feet. In the tunnel on McCampbell property, the limestone was encountered 25 feet from the entrance. On making an offset to the right, soft ore was found which extended to the end of the tunnel, a distance of about 50 feet. The more extensive alteration in this portion of the tunnel doubtless finds its explanation in the presence of fractures permitting the access of water and the consequent leaching of the ferruginous rock. An excellent illustration of this effect of weathering agencies is seen in an outcrop in the north face of the ridge 200 yards southwest of the house of Mr. Snyder's land, in the McCampbell area. Here erosion has removed the products of weathering about as fast as formed. An opening shows the abrupt transition from soft ore to the hard unaltered limestone below. Leaching

has progressed irregularly into the rock following along fractures and crevices which permitted the easy access of surface waters.

Many other instances may be cited where the indications of the concentration of the iron ores through the leaching of the iron limestone are

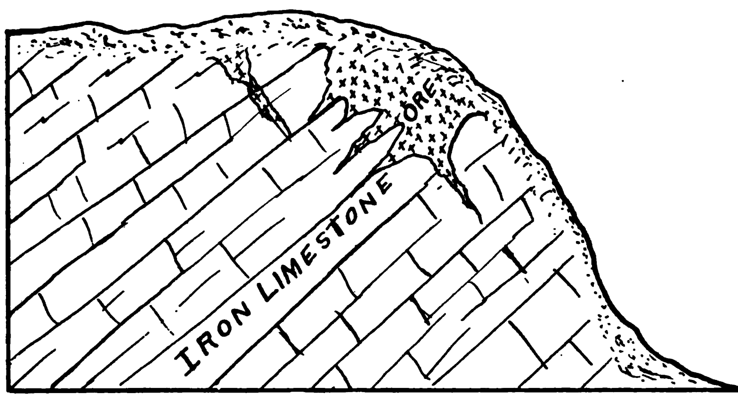


FIGURE 8.—Section showing the derivation of the iron ore from the "iron limestone" by leaching of the lime constituents.

equally clear and convincing. The prospect shaft put down on Joshua Cates's land west of the McCampbell Knob, met with the dark, bluish-gray, calcareous sandstone (see analysis No. 19) at a depth of about 30 feet as indicated by the excavated material. The highly ferruginous character of the calcareous beds of the Tellico is shown also by the analyses given (p. 62). It will be readily seen therefore that with the removal of the lime by leaching the iron constituents will be concentrated and the deposition thus formed will be confined to the surficial or weathered portions of the formation.

MINING CONDITIONS.

Considerable excitement in the Tuckahoe district was aroused about two years ago, resulting in most of the above prospecting work being done. Estimates of tonnage based upon the results of this prospecting work have been made, but in view of the foregoing facts, and an examination of the prospects, the writer is of the opinion, that even in small and restricted areas, not to mention the entire district, no estimates worthy of the name are possible.

In general, with reference to the character of the ores, analyses have shown that good commercial grades occur in parts of the weathered zone. All the ores are relatively high in phosphorous, and therefore non-Bessemer. After passing through the variable, but relatively thin, weathered zone of enriched ore, the veins show a rapid decrease in iron content with increase of depth. This diminution of iron with depth may be expected to continue until the unaltered ferruginous limestone is reached, after

which the iron values will ordinarily vary from 10 to 16 per cent. Under present conditions this material can not be considered an iron ore, though in many places in East Tennessee there are literally mountains of it. Possible other uses may be found for it.

Having thus presented the facts in the case so far as present developments have shown, the question as to whether, under present conditions, these deposits can supply a regular and large tonnage answers itself. If it is possible to mine a deposit that occurs in widths and depths varying between 7 to 20 feet, and 1 to 12 feet respectively, where the values are spotted and irregular; where all the work of removing the materials would have to be done by hand; where the iron ore would have to be delivered by cart, wagon or tramway to some point to be loaded on railway cars; where the topography is that of knobs and ridges, therefore not easily accessible, all at a cost of 75 cents to $1.00 per ton, then mining may pay. Up to the present time no one has essayed the task. Therefore, until some one has demonstrated that these deposits can be worked at a profit, we must put them into the class of possible future reserves rather than consider them an immediate source of supply."

Table of analyses, iron ore prospects in the Tuckahoe district, Tennessee.

No.	Locality.	Prospect No. or Vein No.	Fe per cent.	SiO_2 per cent.	CaO per cent.	P. per cent.	S. per cent.
1	Johnson's Knob	1	48.1	20.16	1.00	0.426	0.06
2	Johnson's Knob	2	28.0	35.12	0.40	......	......
3	Johnson's Knob	3	43.3	20.68	0.60	0.295	0.76
4	Johnson's Knob	Cellar of Johnson's house	50.0	13.32	0.40	0.498	0.27
5	Johnson's Knob	4	33.0	36.3	0.65	......	......
6	Johnson's Dump vein	2	36.7	24.92	0.50	0.453	0.68
7	Vance Farm, select ore	......	51.3	9.78	2.00	1.001	0.42
8	Vance farm, average ore	......	41.2	21.4	1.50	0.831	0.12
9	Moore's Knob	1	43.6	16.88	0.70	0.73	0.65
10	Moore's Knob	2	22.0	5.20	27.20	......	......
11	Moore's Knob	3	34.2	15.2	9.60	......	......
12	Moore's Knob	5	19.8	8.88	26.60	......	......
13	Moore's Knob, northeast	1	23.1	34.10	11.30	......	......
14	Moore's Knob, northeast	2	29.2	40.00	1.20	......	......
15	Moore's Knob, northeast	3	32.4	36.6	1.80	......	......
16	Moore's Knob, northeast	4	41.7	19.00	4.0	1.023	0.45
17	McCampbell's Knob	1	30.5	34.80	1.15	......	......
18	McCampbell's Knob	S. W. prosp	41.4	19.6	2.25	0.836	0.49
19	McCampbell's Knob	Joshua Cates	11.4	45.00	14.80	......	......
20	McCampbell's Knob	Soft ore	40.6	17.20	6.00	0.958	0.55
21	McCampbell's Knob	2	41.0	23.12	0.60	0.648	0.28
22	McCampbell's Knob Tunnel	2	32.0	29.2	1.40	......	......
23	McCampbell's Knob Tunnel	2	34.2	13.20	10.80	......	......
24	McCampbell's Knob	3	42.6	22.0	0.40	0.669	0.55
25	McCampbell's Knob	4	42.5	19.0	1.20	1.082	0.60
26	McCampbell's Knob	5	44.7	13.92	1.75	0.616	0.52
27	McCampbell's Knob	Snyder farm	49.2	14.28	0.90	0.959	0.46
28	McCampbell's Knob	Snyder farm	46.0	14.6	2.40	0.479	0.52
29	McCampbell's Knob	Snyder farm	26.6	6.70	22.5	......	......
30	Sample taken from Tellico formation near Charleston, Tenn	......	14.0	22.6	26.70	......	......

NOTE.—The above analyses are all made on moisture-free samples.—R. P. Jarvis, Analyst.

		Iron.	Insol.	Mn.	P.	Moist.	
31	Johnson's prospect	35.00	31.20	.44	.44	3.10	Childress
32	Johnson's cellar	53.20	9.50	.97	.25	3.40	and Hunter,
33	Vance's prospect	50.40	2.25	Tr.	1.10	1.39	Analysts.

"ROCKWOOD" IRON ORE.

CHARACTER.

Mineralogy.—The "Rockwood" iron ore, so named from its occurrence at Rockwood, Tennessee, contains the iron oxide known as red hematite, (when pure ferric oxide, Fe_2O_3, contains metallic iron, 70 per cent, oxygen, 30 per cent). Red hematite includes the structural varieties known as fossil and oolitic ore. There is but little purely oolitic ore in Tennessee, however, most of the ore containing a mixture of fossil fragments and flaxseed-shaped grains. The mass of the ore is amorphous, red to bluish-black, lustrous hematite mixed with calcium carbonate, silica, alumina, magnesium carbonate, and other minerals in minor quantities. In the text devoted to detailed descriptions notes are given on the various types of ore locally developed.

Structure.—The "Rockwood" ore with its associated minerals occurs in lenticular beds analogous to strata of sandstone, shale, and limestone, and interbedded with such rocks.

The fossil ore consists of aggregates of fossil organic forms such as bryozoans, crinoids, corals, brachiopods, and trilobites. (See Pl. VII.) These fossil forms were evidently originally composed principally of calcium carbonate. There are calcareous streaks in the ore in which many of the fossil fragments are still composed mainly of calcite, but in other places the fossil forms are composed partly or wholly of ferric oxide. Whether this indicates molecular replacement of calcite by ferric oxide or simply a filling by ferric oxide of cavities from which the lime has been dissolved is an interesting question. At present the evidence seems to indicate the latter process. The fossil material, much of which consists of broken and waterworn fragments, evidently was gathered by the action of waves and currents into beds, and subsequently cemented together by calcium carbonate and ferric oxide. More or less clay material has been likewise included in the beds during their formation; this commonly exists as thin seams of shale, and as argillaceous nodules and lenses.

The granular ore consists of aggregates of flat grains with rounded edges, somewhat of the size and shape of flaxseeds. (See Pl. VIII.) These grains generally lie with their flatter sides parallel to the bedding planes of the rock, and the mass is cemented by ferric oxide and more or less calcium carbonate. The flat grains generally have a minute nucleus of quartz, about which iron oxide, and, in some instances, siliceous and aluminous materials have been deposited. In Tennessee the fossil variety of ore generally predominates in a bed, but in certain localities the fossil fragments and the granular bodies are mixed in varying proportions. The more fossiliferous ore, where un-

PLATE VII

FOSSILIFEROUS, HARD, LIMY "ROCKWOOD" ORE FROM UNDERGROUND MINE AT EUCHEE, TENNESSEE (NATURAL SIZE).

Photo by U. S. G. S

PLATE VIII.

Soft, Granular "Rockwood" Iron Ore Showing Slickensides (Natural Size).
Lone Mountain, near Miller's Ferry, Tennessee.

Photo by U. S. G. S.

weathered, as compared with the granular ore in the same condition, is apt to be the more calcareous, while the granular ore may carry higher proportions of silica and alumina.

Chemical composition.—A characteristic of the "Rockwood" ore that is secondary rather than original is that where weathered or acted upon by surface waters the lime carbonate is dissolved out of the beds, thereby increasing the content of iron oxide, silica, and other constituents proportionately. Such altered ore is popularly termed "soft ore," and appropriately, too, for where altered it is usually porous and friable as compared with the unaltered material, which is termed "hard ore." The alteration of the ore beds takes place along the outcrop and at distances of a few feet to more than 500 feet, depending on the attitude of the beds and on the thickness and permeability of their cover. Conditions favoring fairly deep leaching of the ore beds are a rather steep dip and impervious shale at top and bottom of the ore which should outcrop in a ridge high above groundwater level. Below groundwater level the ore is generally hard. The quantity of the soft ore is small as compared to that of the hard ore, and owing to its higher content of iron and its greater accessibility much of the soft ore has already been taken in mining, so that in the future the reserves of this variety of ore will steadily decrease in importance.

When the open-cut mines of the Roane Iron Company near Chamberlain, Tennessee, were visited by the American Institute of Mining Engineers in October, 1908, an interesting exposure of the ore bed containing both hard and soft ore was available for inspection. Surface waters had leached most of the lime from the bed extending down the dip to a fairly definite line which was termed by the miners the "contact" between the hard and soft ores. The writer collected four samples of ore from this bed, two from the hard ore, one several feet from the dividing line, the second near it, and two from the soft ore, one near the line and the other several feet from it. The samples of the soft ore were so leached as to be rather porous, and the color was yellowish brown as compared with the dark red of the hard ore. This change in color is probably due to the alteration of some of the hematite o limonite, and this is borne out by the chemical analyses below which show a higher percentage of combined water in the soft ore than in the hard and semi-hard ore samples.

Chemical analyses and specific gravity tests of these samples were made in the laboratory of the United States Geological Survey, by George Steiger, with the results denoted below. The results illustrate the gradation from hard to soft ore, principally with regard to the increase in iron oxide, silica, and alumina, and the decrease in lime. With the decrease in lime the percentage of the minor insoluble impurities

such as manganese, phosphorus, and sulphur also tend to increase proportionally. The specific gravity tests were made with lumps of ore in the natural state, the exterior surfaces having been coated with paraffin to prevent absorption of water.

Analyses and specific gravity tests of hard, semi-hard, and soft "Rockwood" iron ore from Chamberlain, Tenn.

	1	2	3	4
SiO_2	5.00	7.92	7.63	7.62
Al_2O_3	2.82	3.07	3.64	4.31
Fe_2O_3	36.44	50.60	67.60	74.96
FeO	2.20	2.44	4.47	.10
MgO	1.63	1.71	.50	.47
CaO	24.84	13.77	1.68	.40
Na_2O	.10	.10	.12	.13
K_2O	.22	.25	.33	.30
TiO_2	.11	.10	.26	.12
CO_2	19.89	12.29	3.04	.32
P_2O_5	.99	1.31	1.69	1.22
S	.05	.05	.07	.02
Mn	.30	.33	.58	.31
H_2O-	.89	.59	.84	.66
H_2O+	4.72	5.52	8.15	9.35
	100.20	100.05	100.29	100.60
Fe (from Fe_2O_3 and FeO)	27.22	37.32	52.55	50.79
Specific gravity	3.05	3.09	2.49	2.59

1. Hard ore, large lump, remote from line of division between hard and soft ore.
2. Semi-hard, small slab, near line of division between hard and soft ore.
3. Soft, small slab, near line of division between hard and soft ore.
4. Soft ore, large lump, remote from line of division between hard and soft ore.

Between samples of hard ore taken from place to place along the outcrop and between samples taken from different outcrop areas considerable differences in percentages of iron, lime, silica, etc., are often found. These differences are evidently due to variations in the original sediments. It is interesting to note the differences between soft ores derived from two samples of hard ore which may be termed A and B. The ore (A) is high in lime and low in silica, while (B) is low in lime and high in silica. Even though the ore (A) may have contained less metallic iron than (B) the soft ore derived from (A) may be the richer of the two in iron. It should not therefore be a matter of surprise and disappointment in mining to find that an especially rich soft ore leads to an unusually lean hard ore. These relations may be demonstrated arithmetically. Consider that the hard ores (A) and (B) showed on analysis the percentages of their principal ingredients according to the following table, and that all the lime and magnesium carbonates have been leached out of both ores, then the resulting soft ores would have approximately the com-

positions shown under the headings A[1] and B[1]. This result is obtained by increasing the percentages of the insoluble ingredients proportionally to the loss sustained by the ore through the dissolving out of the soluble carbonates, and leaves the ratios of the remaining constitutents to each other practically the same as in the hard ore.

Analyses showing effect of leaching "Rockwood" ores.

	A hard ore.	A[1] resulting soft ore.	B hard ore.	B[1] resulting soft ore.
Ferric oxide (Fe_2O_3)	36.44	67.93	47.64	56.21
Silica (SiO_2)	5.00	9.32	15.35	18.14
Alumina (Al_2O_3)	2.82	5.25	8.60	10.17
Lime (CaO)	24.84	.....	6.88	.....
Magnesia (MgO)	1.63	.....	1.50	.....
Carbon dioxide (CO_2)	19.89	.....	7.05	.....
Metallic iron (Fe)	25.51	47.55	33.35	39.35

Conditions of blast-furnace practice define the grade of material that may be regarded as an ore. For instance, a lower limit of metallic iron and a higher limit of impurities may be allowed in a limy ore than in one that contains but little lime. In localities where brown iron ore or "soft" "Rockwood" ore is available for mixing with limy "Rockwood" ore, an ore of the latter type can be used as a flux in many instances, although it runs so low in iron and so high in lime that it might not be regarded as acceptable in districts where no brown ore or "soft" ore can be used. In general, the hard "Rockwood" ores used today in Tennessee blast furnaces range in percentages of major constituents as follows: Metallic iron, from 25 to 45 per cent; lime oxide, from 8 to 20 per cent; magnesia, from 1.50 to 4.5 per cent; silica from 4 to 15 per cent; alumina, from 4 to 10 per cent; phosphorus, from 0.25 to 0.75 per cent; sulphur, from a trace up to 1 per cent; and water from 0.5 to 6 per cent. The ore is of non-Bessemer grade. Small quantities of manganese are found in the ore in places. The content of this mineral seldom exceeds 0.5 per cent. In the soft ore the lime generally runs less than 1 per cent, so that the percentages of the other constituents are proportionately higher, the metallic iron ranging generally between 40 and 58 per cent. Semi-hard ores show all gradations between hard and soft ores.

Specific Gravity.—The "Rockwood" ore exhibits rather wide variation in specific gravity due (a) to variations in compostiion, and (b) to variations in structure. By experiments with 1-inch cubes and lumps of ore [1] the specific gravities of samples of hard "Rockwood" ores in Tennessee have been found to range from 3.05 to 3.36, and soft ores from 2.49 to

[1]Experiments by George Steiger, U. S. Geol. Survey, and W. M. Mills, Chemist, Roane Iron Company

2.93. The above figures with regard to hard ore correspond roughly to weights of 190 to 210 pounds per cubic foot, and to volumes of 11.8 to 10.7 cubic feet per long ton, and those for soft ores indicate weights of 155 to 183 pounds per cubic foot and volumes of 14.5 to 12.25 cubic feet of ore per long ton.

Probable origin and its economic significance.—It is now generally accepted that the "Rockwood" iron ore was formed by the deposition in a body of water of sediments containing iron, together with calcium carbonate, silica, alumina, and other minerals in minor proportions. The chemical condition of the original iron-bearing sediments has not yet been satisfactorily determined. Much of the calcium carbonate was evidently deposited in the form of fragments of fossils such as brachiopods, molluscs, and crinoid stems. There has been replacement of much of the calcium carbonate in the fossils by iron oxide, and recrystallization of some of the calcium carbonate into calcite in the ore. The interchange between the calcium and iron minerals may have taken place very early in the history of the beds, perhaps even before they became consolidated, and it probably involved only the original sediments. There is no evidence that iron has been introduced from other beds either in the "Rockwood" or adjacent formations, or that the deposits are of the replacement type as that term is generally understood. The question as to the character of the original sediments, although of great interest from a scientific standpoint, has but little bearing on practical developments of the ores, but the larger question, that of the origin of the deposits themselves, has a very practical bearing on the extent and quality of unexploited ore.

As stated above, the process of original deposition is now generally believed to have been mainly responsible for the formation of the "Rockwood" iron ore beds, and it is not necessary here to present arguments for this view nor against any of the opposing hypotheses, since this matter has been recently rather fully discussed in literature that is still available.[1] The accompanying photograph illustrates the striking resemblance of a bed of "Rockwood" iron ore to a bed of water-laid sandstone. (See Pl. IX.)

The only conception regarding the character and genesis of the "Rockwood" iron ore that appears to need correction here is the one which was given wide circulation in the U. S. Geological Survey folio descriptions of East Tennessee quadrangles published between 1894 and

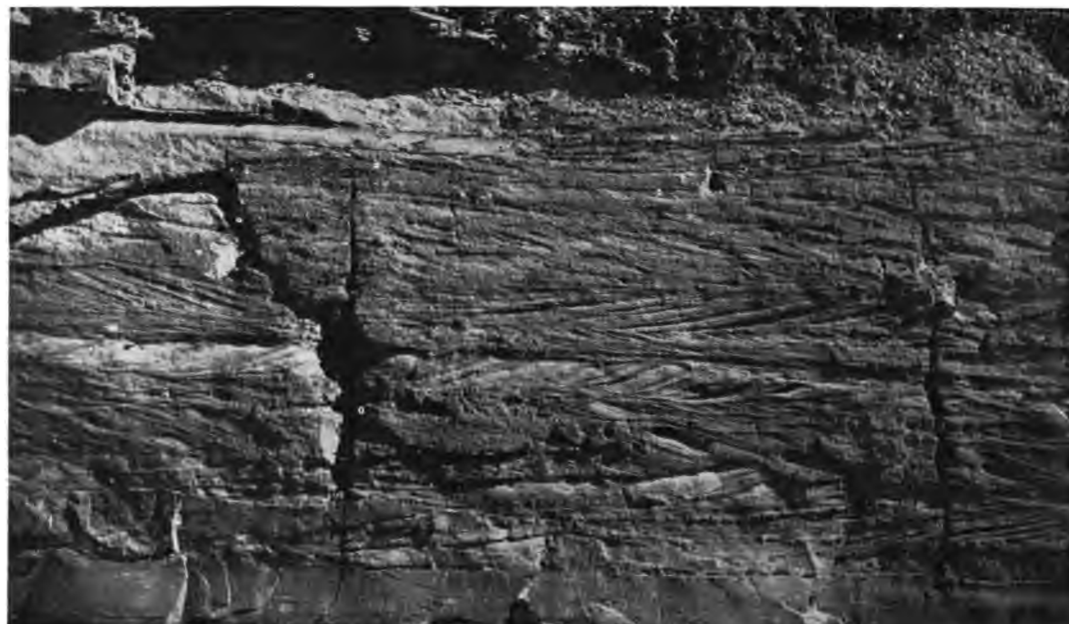
[1]See Smyth, C. H., Jr., On the Clinton iron ore: Amer. Jour. Sci., 3d ser., vol. 43, No. 258, June, 1892, p. 487–496.

Smyth, C. H., Jr., The Clinton type of iron ore deposits: Types of ore deposits, by H. F. Bain and others, 1911, pp. 33–52.

Eckel, E. C., Origin of the Clinton ore: Bull. U. S. Geol. Survey, No. 400, 1910, pp. 28–39.

Burchard, E. F., Clinton ores of Birmingham district, Alabama: Bull. U. S. Geol. Survey, No. 315 1907, p. 149; also Bull. 340, 1908, pp. 308–317; and Bull. 400, 1910, pp. 40 and 125.

PLATE IX.



CHAMBERLAIN, TENNESSEE—BED OF "ROCKWOOD" HARD ORE SHOWING CROSS BEDDING ACCENTUATED BY SOLUTION ALONG JOINT PLANE.

Photo by E. F. Burchard.

1901, and which considered that the ore beds are merely the weathered outcrops of ferruginous limestone, the lime having been leached out above water level, leaving the insoluble portion of the limestone in a concentrated form. So far as the soft ore at or near the outcrop is concerned, this idea is correct, but the statement, "The proportion of iron in the ore usually decreases with distance from the surface, and at considerable depths it becomes simply a more or less ferruginous limestone," has been proved by mining and drilling to be erroneous with regard to the "Rockwood" beds. In the case of the "Tellico" ore which is residual from ferruginous limestone the statement holds good. At the time the *early* folios were published there was little to indicate that the "Rockwood" hard ore really extended practically unchanged in character throughout the extent of the beds, yet as late as 1901 the earlier view was still current, as is indicated by the following statements in the text of folio No. 75, descriptive of the Maynardville quadrangle.

"When the fossil ores are worked down to the water level of the adjacent country the percentage of iron is so much less that they are practically limestones and are valueless as ores. Here the amount of ore is strictly limited by the water level, and as the layers which contain the ore always occupy low ground, the amount of ore is much less than would be supposed."

In the course of several season's field work in Alabama, Georgia, and Tennessee, it has been observed that the ore, where soft at or near the outcrop, merges more or less gradually with depth into hard ore of fairly uniform composition. This fact indicates clearly that the soft ore has been derived by a secondary process from the hard ore, but it does not furnish any suggestion concerning the genesis of the hard ore itself. The mode of occurrence and the constitution of the hard ore do not indicate that it has resulted from the alteration of a rock originally very different in composition, or that it is directly residual from disintegration of rocks containing minor quantities of iron minerals. The hard ore must therefore be regarded as having been formed in essentially its present condition contemporaneously with the inclosing sandstone and shale of the "Rockwood" formation. Acceptance of this view leads to the conclusion that no regular decrease in iron content is to be expected as the ore beds are explored to greater depths than those already attained.

As to the extent of the beds, observations in mines and along the outcrops, as well as general studies of the stratigraphy, show that the ore beds, in common with the other strata in the "Rockwood" formation, are built up of overlapping thin lenses or layers of sedimentary material. As a whole the "Rockwood" formation exhibits this lenticular structure, and therefore the ore beds also probably were originally lenticular in shape, and the ore lenses were comparable in length and width with sandstone and shale lenses in the formation. The lenses are of course

very flat and thin in proportion to their other dimensions, and they appear to thin to a feather-edge in some directions, while in others they split into thin seams and dovetail with lenses of shale and sandstone near their extremities. The lenses of sandstone, ore, and shale composing the "Rockwood" formation probably were deposited in a nearly horizontal attitude, or at least with a low initial dip. Folds, faults, and erosion have so tilted, broken apart, and worn away portions of the rocks that it is difficult to recognize in the present outcropping beds portions of what probably were at one time well-defined, lens-like bodies of ore.

The processes of sedimentation by which the beds of sandstone, shale, and iron ore were formed probably were similar to those now operating along the south Atlantic coast of the United States, except that the water bodies were probably narrow bays and lagoons rather than an open ocean. The sediments composing the present shore deposits are carried by many short rivers from the highlands of crystalline rock across a narrow, low, coastal plain, and deposited a short distance off-shore in comparatively shallow water. Through the sorting action of currents, and to a less extent that of waves, the sediments are spread along the shore line in such a way that they are homogeneous in character for much greater distances parallel to the shore line than at right angles to it.

Stratigraphic and paleontologic studies in the southern Appalachians have indicated that certain of the Paleozoic formations between the Cambrian and the Carboniferous were deposited in long narrow bays or estuaries, and this seems to have been characteristic of the "Rockwood" deposits. While the axes of folding may not extend exactly parallel to these ancient shore lines it is believed that in general these directions coincide fairly closely in the southern Appalachian region. In other words, the axial directions of the folds denote the general directions of the old shore lines. Under the conditions here outlined the thickness of the ore beds as well as that of their inclosing rocks may be expected to change more abruptly in the direction of their dip than in the direction of their strike. Where ore beds that are workable on the outcrop pass below the Cumberland Plateau, the change in thickness, if any, will probably not be great enough to affect the availability of the ore within depths to which it is practicable to mine it, and it is also possible that in places the ore beds may become thicker for certain distances rather than thinner, in the direction of the dip. Folding of the strata has in places so squeezed the ore that rather abrupt local thinning and thickening has been produced. Notwithstanding the possibility of many such variations in thickness, it should be possible by measurements on the outcrop and in drillings to ascertain nearly the average thickness of the bed, and by using other factors, such as the specific gravity of the ore based on its

chemical composition, and the per cent of recoverable ore, a fairly close approximation to the tonnage of available ore in a given area can be computed.

GENERAL DISTRIBUTION.

The "Rockwood" ore in East Tennessee outcrops along the foot of the Cumberland escarpment from the southern border of the State below Chattanooga to the northern border of the State at Cumberland Gap and in several separate areas in the Tennessee Valley. (See Pls. I to V.) The Cumberland outcrop is not continuous because a number of thrust faults have buried the formation below older rocks in places. There are, however, strips of outcrop that extend distances of 15 to 20 miles continuously. The normal dip of the rocks along the escarpment is toward the northwest, but in many places the ore beds dip to the southeast or away from the mountain. This reversed dip is due to the strata having been overturned during the folding of the earth's crust, and it extends from a few feet to hundreds of feet below the surface, but if the beds are followed to sufficient depths they will be found to curve backward until the dip is toward the northwest. The iron ore beds extend under the Cumberland plateau for unknown distances. In the northeast part of the State it is very probable that the bed is continuous between Powell Valley and Elk Valley (see section, Fig. 25), the outcrop in Elk Valley being due to faulting and erosion. Near Caryville the southwestward extension of the ore is cut off by a cross-fault, which extends northwest as far as Elk Valley and here again cuts off the ore that is exposed in that valley, thus forming a block of strata bounded on the southeast by Powell Valley, on the southwest by Coal Creek, on the northwest by Elk Creek, and on the northeast by a fault which passes through Cumberland Gap. Along the escarpment between Coal Creek and Harriman the ore is cut out locally by several thrust faults, so that only three limited areas of outcrop are found. From Emory Gap southwest to near Glen Alice the ore outcrop is more or less continuous, and in this area from Cardiff to Rockwood occurs one of the thickest and most valuable portions of the ore lense that has been opened anywhere in the State. Between Glen Alice and Spring City there is one important break due to faulting, but southwest from Spring City to Retro the ore outcrop is practically continuous. Between Retro and Rathburn there is a break followed a by strip of ore outcrop measuring about 2¼ miles in length, beyond which no ore is found until the valley of Falling Waters Creek is reached. From Falling Waters Creek southwestward to the State line the ore outcrop is practically continuous, and it is duplicated on both sides of a narrow anticlinal arch. This arched structure also occurs from Hill City southward to the State

line in a second outcrop which occurs one to two miles east of the main outcrop at the foot of the Cumberland escarpment, and passes through the city of Chattanooga.

In the Tennessee valley the several areas of "Rockwood" ore are formed by beds that have been folded in among strata of earlier age. The most important of these are situated near Chamberlain a few miles south of Tennessee River in Roane County and along Tennessee River near Euchee, Meigs County. These outcrops are mostly in the form of synclinal basins of "Rockwood" formation modified by more or less folding, faulting and erosion. Just northeast of Decatur a small area occurs which is bounded on the east by a fault, and farther south, Whiteoak Mountain forms the west limb of a syncline in which ore occurs extending from the State line northward several miles from Ooltewah. Soft ore has been stripped from the outcrop along nearly the whole extent of outcrop in the State, the only exceptions being in localities too remote from railroads or navigable streams. The ore has been mined underground at La Follette; to a very small extent near Elk Valley; extensively between Emory Gap and Rockwood; a few small drifts or tunnels have been driven near Glen Alice. Considerable underground work has been done in the vicinity of Chamberlain and Euchee, and a little near Ooltewah. The possibility of underground mining has of course depended upon the thickness of the ore bed and upon the quality of the hard ore below the limit of weathering, as well as upon transportation facilities.

An attempt has been made to distinguish on the maps which accompany this bulletin between ore that is available, or probably available, underground, and ore that is not available under present conditions. In the latter class is included ore seams that are so thin as to give no promise of future value and others that probably will not become workable until some time in the remote future when the reserves of more readily available iron ore in the country have become more nearly exhausted and the price has reached a point which will permit of exploitation of such ores. Under the detailed descriptions will be found data with regard to the thickness, attitude of the beds, quality of the hard ore at all places along the outcrop where it was possible to make examinations during the past several years. Topographic maps have been prepared by the U. S. Geological Survey covering this whole area, and with two small exceptions the area has been covered by geologic folio maps. The two areas not covered by geologic folios are included in the southern portions of the Williamsburg and Cumberland Gap quadrangles. The geologic folios that cover the remainder of the area are as follows, reading from north to south: Briceville (No. 33), Maynardville (No. 75), Knoxville (No. 16), Loudon (No. 25), Kingston (No. 4), Pikeville (No. 21), Sewanee (No. 8), Chattanooga (No. 6), and Cleveland (No. 20). A

strip about 1 mile wide at the north edge of the Stevenson (Folio No. 19) and Ringgold (Folio No. 2) quadrangles completes the area within the State of Tennessee to the south of the Sewanee and Chattanooga quadrangles. In these folios the general geology and structure have been described by means of maps, structure sections, and discussions in the text. For the purpose of this bulletin it is not regarded as essential that the geology of the region be discussed except in so far as it has a direct bearing on the iron ore beds. In certain of the geologic folios the distribution of the "Rockwood" formation has been shown to be more extensive than it is now believed to be. At the time the folio surveys were made few data were obtained with regard to the ore beds, and it was assumed that the ore did not extend much below water level. The continuity of the beds with depth has been proved by recent mining work. In Sequatchie Valley, in the Pikeville, Chattanooga, and Sewanee quadrangles, recent work by E. O. Ulrich has indicated that much of the formation formerly mapped as "Rockwood" may not be of Clinton age but older, and that it does not carry ore beds of sufficient importance to be noted in this bulletin. Such areas have consequently been omitted from the maps showing the distribution of ore outcrops. In the lower part of Sequatchie Valley near Jasper beds of ore have been mined extensively both on the outcrop and underground a number of years ago, but northward from the vicinity of the old Inman mines the ore thins abruptly and in a short distance becomes so lean that it is unfit for consideration.

If placed end to end the outcrops of "Rockwood" ore along the base of Cumberland escarpment, considering but a single seam, aggregate 160 linear miles. If the Valley outcrop be similarly considered it brings the total linear outcrop of "Rockwood" ore beds in the State up to 245 miles. Out of this total, probably 60 miles of outcrop may be considered as workable for hard ore, so far as quality and thickness are concerned, to whatever distances below the outcrop that may be permitted by mining conditions. These linear distances were determined by scaling off the outcrops as shown in the geologic folios. By measurement on the ground the distance might be appreciably greater because the scale of the maps is too small to show many sinuosities of the outcrop.

SOUTHEAST TENNESSEE.

Cumberland Escarpment Area.

General statement.—The "Rockwood" ore in this portion of the State outcrops along the foot of the Cumberland escarpment, with the exception of about 6 miles in the vicinity of Daisy, continuously from the Georgia line northeast to beyond the limit of the area considered, which is between Evensville and Sheffield. This area lies principally in the

Chattanooga quadrangle, but includes small portions of the Pikeville and Kingston quadrangles. (See Pl. II.)

The "Rockwood" outcrop between the State line and the creek called Falling Waters is doubled by an anticlinal fold, the east limb of which dips toward the Tennessee Valley, and the west limb toward Walden Ridge. Mountain Creek flows along the axis of this anticline which south of Tennessee River passes to the west of Lookout Mountain into Lookout Valley. Another anticline carrying iron ore outcrops on its flanks, extends northward from the east side of Lookout Mountain to Hill City. The east limb of this fold is bordered by a fault which has buried most of the ore-bearing formation. The outcrops of ore at Hill City and on Moccasin Bend are in this area. The ore beds on the west side of this anticline are considered to be continuous with those dipping eastward on the flanks of the Mountain Creek-Lookout Valley anticline, so that south of Moccasin Bend the beds pass below Lookout Mountain, forming an intermediate syncline. The general relations of the strata are shown in the cross section, Fig. 10.

The ore-bearing strata nearest to Walden Ridge form the east limb of a broad syncline or basin which may be considered as co-extensive with the table land between the Cumberland escarpment and Sequatchie Valley. The distance from a point on the outcrop of the "Rockwood" formation south of Williams Island northwest to the Inman locality, where it appears in Sequatchie Valley, is about 10 miles, and it is not improbable than an ore bed is present in the formation from one edge of this basin to the other, but whether the same bed of ore is continuous is problematical. Instances in which one bed thins out and another bed develops in the section either above or below the first bed have been observed in many places in Tennessee, Alabama, and Georgia. It has also been observed that an ore bed may thin and disappear without an equivalent bed being developed in the section in the immediate vicinity, although this instance is less common. It is also a well-established fact that in this general region changes in the character of formations are more abrupt in a northwest-southeast direction than in a northeast-southwest direction.

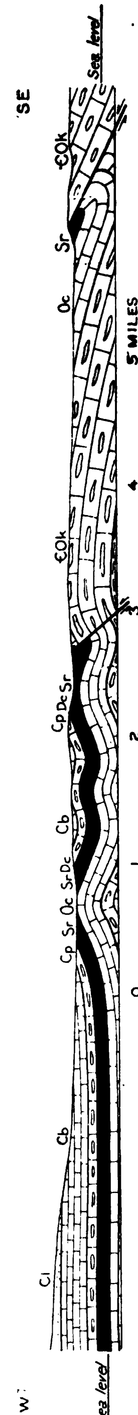


FIGURE 10.—Northwest-southeast section near Chattanooga. (From U. S. Geological Survey Folio No. 6.)
€Ok, Knox dolomite. Oc, Chickamauga limestone. Sr, "Rockwood" formation. Dc, Chattanooga shale
Cp, Fort Payne chert. Cb, Bangor limestone. Cl, Walden sandstone.

Chattanooga quadrangle, but includes small portions of the Pikeville and Kingston quadrangles. (See Pl. II.)

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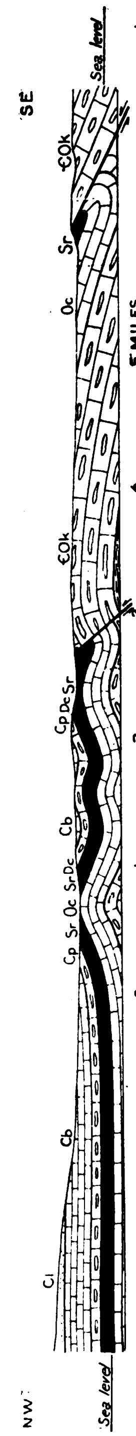

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(The probable reasons for this are discussed on pp. 79 and 80.) It is even possible that a formation in whole or in large part may not be found in its logical place in a section simply because it was never deposited with the other sediments at that place. Recent discoveries bearing on this phase of the local geology indicate that the "Rockwood" formation is wanting in large part if not entirely absent below that part of Walden Ridge adjacent to Sequatchie Valley northeast of the Marion-Sequatchie County line. Consequently no "Rockwood" ore can be expected in the upper half of the Sequatchie Valley.

At the base of the southeast escarpment of Walden Ridge the ore outcrops continuously except where faulted out, but how far to the northwest below the plateau the beds may extend may never be determined except by drilling The expense for the requisite amount of drilling necessary to shed much light on this phase of the extent of the ore beds would be considerable, since the ore, according to what is known of the thicknesses of the rocks overlying it in Walden Ridge probably lies at depths ranging between 1,850 to 2,200 feet below the general level of the plateau. In places where streams have cut their beds 400 to 500 feet below the plateau the ore should be reached at correspondingly less depths, and in the southern part of the basin where Tennessee River cuts a deep gorge through the plateau, it seems possible that the ore might be reached at depths of 750 to 900 feet along the river between Stanley and McNabb. The poor character of the ore beds outcropping on the margins of Walden Ridge in this vicinity will probably discourage deep drilling in the immediate future, although the fact that the thickness of the ore may increase in places below cover should not be lost sight of.

Mountain Creek-Lookout Valley syncline.—The great variability in the "Rockwood" ore beds is well illustrated by sections made at various places on the outcrop along both limbs of this fold. The thickness of the ore seams ranges from 5 inches to 33 inches, according to 15 or more measurements. In places there are two to four seams of ore within a 20-foot section of the formation. The hard ore is, as a rule, highly calcareous, with a correspondingly low percentage of iron oxide, and has not been mined here to any extent. Some soft ore has been obtained from surface trenches on the east limb of the anticline, both northeast and southwest of Wauhatchie, and some was dug from the outcrop south of the Southern Railway grade on the west limit of the anticline, about the year 1894. The most accessible portions of the area are of course those adjacent to the Nashville, Chattanooga, and St. Louis Railway, the Southern Railway grade, and near Tennessee River. If the ore north of Tennessee River near Mountain Creek were considered sufficiently valuable, a track could be laid from Tennessee River up the

valley of Mountain Creek so as to reach 4½ miles of double outcrops, and the ore could be floated to Chattanooga on the river. The upper end of this anticline might be reached by a short spur from the Cincinnati, New Orleans, and Texas Pacific Railway north of Hixson.

The following nine sections indicate the essential features of the ore in this portion of the field.

Section of "Rockwood" ore in Nashville, Chattanooga and St. Louis Railway cut, two miles southwest of Wauhatchie.

(Pl. II, 1, and corresponding ore section.)

	Feet.	Inches.
Shale	..	..
Ore	..	6
Shale and shaly ore	..	1½
Ore	..	4
Shale with thin limestone parting in middle	..	10½
Ore, hard, lean, calcareous, with a few nodules of argillaceous material. Very fossiliferous	1	5½
Shale	..	4½ to 5½
Ore, similar to above	1	1
Shale	..	1½
Ore	..	3
Shale.		

Total ore, mostly lean, 3 feet 7½ inches.

Sections of "Rockwood" ore in Southern Railway grade about 2 miles north of Wauhatchie.

(Pl. II, 2, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, hard, calcareous, of fair quality only where leached	1	3
Shale	..	3–4
Ore, hard, very calcareous	..	10–12
Shale	..	4
Limestone, slightly ferruginous	..	4–5
Shale.		

Dip 15° N. 65° W.

Total ore, mostly lean, 2 feet 2 inches.

Sections of "Rockwood" ore in Southern Railway grade 2¼ miles north of Wauhatchie.

(Pl. II, 3, and corresponding ore section.)

Shale.	Feet.	Inches.
Ore, hard	..	2
Shale	..	2
Ore, hard, calcareous, fossiliferous, with streaks of nearly pure calcium carbonate	1	1
Shale	..	3
Ore, like above	..	10
Shale.		

Dip 15° N. 65° W.
Total ore, mostly lean, 2 feet 1 inch.

Section about 500 feet northeast of above section.

(Pl. II, 3, and corresponding ore section.)

Shale.	Feet.	Inches.
Ore, hard, calcareous	1	5
Shale.		

Dip 15° N. 65° W.

Section including two "Rockwood" ore seams one-half mile south of Williams Island.

(Pl. II, 4.)

	Feet.	Inches.
Shale and thin-bedded limestone.		
Ore, hard, lean, calcareous	..	10
Shale and shaly limestone	7	..
Ore, hard, like above	..	4
Shale and shaly limestone.		

Dip low, toward northwest.
Total ore, mostly lean, 1 foot 2 inches.

Section of "Rockwood" ore one-fourth mile east of Williams Island.

(Pl. II, 9, and corresponding ore section, also Pl. X.)

	Feet.	Inches.
Shale.		
Ore, hard, calcareous, fossiliferous	2	4
Shale.		

Dip 32° S. 50° E.

Section of "Rockwood" ore east side of Mountain Creek about one mile above mouth of creek.

(Pl. II, 10, and corresponding ore section.)

Shale.	Feet.	Inches.
Ore, soft	1 to 1	4 to 5
Shale	..	1
Ore, soft	..	2

Dip 22° S. 54° E.
Total ore, 1 foot 6 inches.

Section of "Rockwood" ore 3¼ miles northwest of Hixson.

(Pl. II, 11, and corresponding ore section.)

	Inches.
Shale, sandy.	
Ore, hard, limy	7
Limestone, argillaceous and slightly ferruginous	2–3
Limestone, ferruginous	4–6
Shale.	
Dip 10° to 15° S. 40° W.	

On the east limb of the anticline about seven-tenths mile northeast of the point where section No. 11 was measured, considerable float ore was noted in a small stream bed Some slabs of ore measuring seven inches in thickness were found and one ledge was found in place which measured five inches in thickness. There may be two thin ledges of ore in the shale in this locality, which is indicated by the point numbered 12 on the map, Pl. II.

On the north side of Falling Waters five beds of ferruginous limestone, or lean, hard ore, are exposed in a deep road cut. None of these beds are thick enough at this exposure or rich enough in iron to be mined independently, and the thick partings of shale between the beds make it impracticable to mine any two of them together. A photograph of this exposure is shown in Pl. X.

The following section was measured here:

Section of portion of "Rockwood" formation on the north side of Falling Waters, 4 miles northwest of Hixson.

(Pl. II, 13, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, hard, calcareous, fossiliferous	1	..
Shale, with thin bands of limestone	1	9
Ore, hard, calcareous	1	1
Shale, with thin bands of limestone	2	11
Ore, hard, calcareous	..	10
Shale	..	1 to 2
Ore, hard, calcareous	..	2 to 3
Shale, with thin bands of limestone near middle	2	3
Ore, hard, calcareous, with knife-edge shale partings near top	..	11
Shale	..	2
Ore, knife-edge to	..	3
Shale, with thin bands of hard sandstone, and argillaceous, ferruginous limestone	7	..
Ore, hard, calcareous	..	3 to 6
Shale	7	6
Ore, hard, calcareous	..	4½ to 6
Limestone	..	6 to 7½
Ore, hard, calcareous	..	2½
Shale.		
Dip 18° S. 65° E.		
Total ore, mostly lean, 5 feet 3 inches.		

PLATE X.

Two Miles Northwest of Chattanooga, Tennessee. Exposure of Bed of "Rockwood" Iron Ore.

Photo by E. F. Burchar

PLATE XI

TEN MILES NORTH OF CHATTANOOGA, TENNESSEE—THREE BEDS OF "ROCKWOOD" IRON ORE INDICATED BY HAMMERS AND BAG.

Photo by E. F. Burchard

This section is of interest chiefly for the information it furnishes with regard to the "Rockwood" formation. The ore seams contain streaks that are nearly pure crystalline limestone, but there are streaks that are so ferruginous that if analyzed alone would probably show a content of 35 per cent of metallic iron. An analysis by the U. S. Geological Survey of the hard, calcareous ore measuring 1 foot 1 inch in thickness near the top of the section showed but 12.53 per cent of metallic iron. If averaged together the material from all the beds might not show more than 20 per cent of iron.

These beds are very ferruginous, fragments of bryozoans and brachiopods and mollusc shells being the most common types of fossils present. Many of the fossils are of pure calcium carbonate.

Hill City and Moccasin Bend.—Owing to their proximity to the Chattanooga blast furnaces the ore beds near Hill City have been worked extensively for soft ore on the outcrop, and to some extent underground, by means of shallow drifts above water level. The ores generally dip steeply here but both the angle and direction of the dip are so variable that underground work is thereby much handicapped. The ore in this anticline is thicker than that along Mountain Creek.

The following sections indicate the general character of the beds in this locality.

Sections of "Rockwood" ore 1.3 miles north of the Hill City-Chattanooga bridge.

(Pl. II, 8, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, soft, good quality	2	4½
Shale	..	2
Ore	..	9½
Shale.		
Dip 20° N. 15° E.		
Total ore, 3 feet 2 inches.		

(Same location as above.)

Shale.		
Ore, soft, good quality	1	8
Shale	..	1½
Ore	1	1
Shale.		
Dip 20° N. 15° E.		
Total ore, 2 feet 9 inches.		

(Same location as above.)

Shale.		
Ore, soft, good quality	1	7½
Shale	..	3
Ore	1	..
Shale.		
Dip 20° N. 15° E.		
Total ore, 2 feet 7½ inches.		

The dip at this point is generally about 20° N. 15° E., but it varies considerably within short distances, so that the ore bed might be difficult to follow underground. The formation is mainly shale, which is much contorted by folding, and easily slumps down when exposed to the air. On this account any underground openings would have to be timbered. The soft ore has been mined here as far as it was practicable to strip off the overburden. There is considerable hard ore and some soft ore still available. The thickness of the soft ore is in many places sufficient for mining, and it is probable that the thickness of hard ore would be slightly greater, owing to the fact that after the lime is leached out of a bed the ore becomes more compact and slightly thinner.

Section of "Rockwood" ore about .85 mile northwest of Hill City-Chattanooga bridge.

(Pl. II, 7, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, hard, calcareous, oolitic, and fossiliferous, good quality	2	..
Shale	..	3 to 5
Ore, hard, calcareous, lean, varying in thickness from 11 inches to	1	3
Shale.		

Dip low, N. 15° W.
Total ore, 3 feet 3 inches.

The dip of the ore in this section is low toward the northwest, but it is not at all uniform in this locality. Within a few hundred yards of this pit a cut on the main wagon road shows a series of closely compressed folds. The abandoned soft ore workings at this point are extensive, and the trenches may be traced continuously to the point where sections shown at point No. 8, Pl. II, were measured, a distance of at least a mile. The thickness of the overburden that has been removed reaches nine or ten feet in places. It is probable that considerable ore lies above water level here and that it might be mined from an underground haulway with upraises. The following sections of "Rockwood" ore were measured at the Kuntz and Ryan mines, Hill City, in 1906.

Section of main seam "Rockwood" iron ore in new entry at Kuntz and Ryan mine, Hill City, 1906.

(Pl. II, 6, and corresponding ore sections.)

	Feet.	Inches.
Shale.		
Ore, soft, with a few wedges of shale ½ to 1 inch thick	2	4
Shale	..	4–6
Ore, soft	..	10–13
Shale.		

Dip steep toward northwest.
Total ore, 3 feet 5 inches.

Section of main seam "Rockwood" iron ore, in old entry at Kuntz and Ryan mine, 1905.

	Feet.	Inches.
Shale, hard, forming roof.		
Ore, soft	2	3
Shale	..	6
Ore, soft	..	6
Shale.		

Dip steep toward northwest.
Total ore, 2 feet 9 inches.

Section of "Rockwood" iron ore on outcrop of main seam at Kuntz and Ryan mine, 1906.

	Feet.	Inches.	
Shale.			
Ore, soft	..	5	This part ranges from 1 ft. 8 in. to 2 ft. 10 in. thick.
Shale	..	1	
Ore, soft	1	4	
Shale	..	7	
Ore, soft	..	8	Ranges from 6 in. to 1 ft. 6 in. thick.
Shale.			

Dip about 50° to 55°, N. 50° W.
Total ore, 2 feet 5 inches.

The strata are very much folded here. In general the dip is 50° to 55° N. 50° W., but according to the miners the ore bed is rarely followed for a distance of 50 feet without some change in the dip being encountered. The ore obtained here in 1906 was soft. Shipments were made by wagons to the Citico blast furnace, and some ore was hauled to the Cincinnati, New Orleans, and Texas Pacific Railway, and sent to the Roane Iron Company's blast furnace at Rockwood. The attitude of the ore bed at one of the openings is shown in Fig. 11.

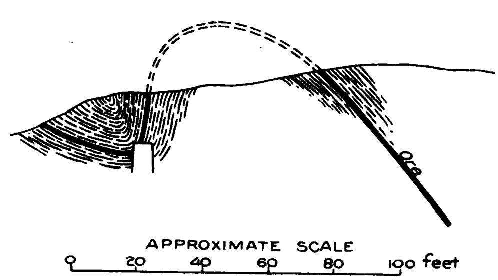

FIGURE 11.—Section showing fold in "Rockwood" iron ore bed at mouth of mine entry, Hill City.

Section of "Rockwood" ore, J. J. Smith's mines, Hill City, 1903.

(Main seam.)

(Pl. II, 6, and corresponding ore sections.)

	Feet.	Inches.
Shale.		
Ore, soft with streaks of shale about 6 inches from top.....	1	7 to
	1	10
Shale..	..	2 to 7
Ore, soft..	..	5 to 8

Dip 59° N. 60° W.

Total ore, 2 feet to 2 feet 6 inches.

(Lower seam.)

	Feet.	Inches.
Shale.		
Ore, soft..	2	..
Shale..	..	3
Ore, soft..	..	10
Shale.		

Dip 12½° N. 30° W.

Total ore, 2 feet 10 inches.

The upper seam dips 59° N. 60° W., while the lower dips only 12½° N. 30° W. on the outcrop. The lower seam at this point was not opened directly below the upper seam but a little distance to one side.

About 1 mile southwest of Hill City near Brown Ferry wagon road a hole was drilled by private parties to the ore bed, which is reported to have been reached at a depth of 345 feet. The core from this drill hole indicated a thickness of approximately 33 inches of ore, if measured perpendicularly to the bedding. The ore is hard, limy, and fossiliferous, the core showing fragments of corals. The roof is hard shale and the bottom of the bed is underlain by hard, shaly limestone.

Section of "Rockwood" ore from drill hole near Brown Ferry road, Moccasin Bend.

(Pl. II, 5, and corresponding ore section.)

	Feet.	Inches.
Shale, hard and dark.		
Ore, hard, limy, fossiliferous (thickness corrected for 30° dip)	2	9
Shale, hard, limy.		

Dip 30° toward northwest.

Daisy.—As stated on page 83 there is near Daisy an interruption on the outcrop of the "Rockwood" ore in the foothills of Walden Ridge. About one-half mile north of Falling Waters the Mountain Creek anticline pitches at a low angle to the northeast below the Fort Payne chert and the Bangor limestone, and the "Rockwood" formation does not again appear until a point is reached about midway between Daisy and Rathburn. The formations that overlie the "Rockwood" have been faulted down to the level of the Knox dolomite about one-half mile east of the Cincinnati, New Orleans, and Texas Pacific Railway. From

the point between Rathburn and Daisy where the "Rockwood" reappears the outcrop of the formation is continuous northeastward. A section was measured 1½ miles northeast of Daisy which showed three thin seams of iron ore parted by shale.

Section of "Rockwood" ore 1½ miles northeast of Daisy.

(Pl. II, 14, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, hard	..	8
Shale	3	8
Ore	..	9
Shale	1	11
Ore	1	2
Shale.		

Dip 25° northeast.
Total ore, 2 feet 7 inches.

Retro.—West and north of Retro the "Rockwood" formation was found to carry two thin seams of iron ore. The ore is not of high quality. The following seams were measured in this vicinity.

Section of lower seam "Rockwood" ore 1 mile north of Retro.

(Pl. II, 15, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, hard, lean, sandy	1	3
Shale.		

Dip 35° northeast.

Section of lower seam "Rockwood" ore 1¼ miles north of Retro.

(Pl. II, 16, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, hard, lean	1	3
Shale.		

Dip 30° northeast.

Section of upper seam "Rockwood" ore 1¼ miles northwest of Retro.

(Pl. II, 16, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, hard	..	9
Shale	2	4
Ore, hard	1	3
Shale.		

Dip 24° N.
Total ore, 2 feet.

Sale Creek.—Only a very thin seam of iron ore was noted in this vicinity. The following section was measured.

Section of "Rockwood" ore near Rock Creek 1¼ miles northeast of Sale Creek Postoffice.

(Pl. II, 17.)

	Inches.
Shale.	
Ore, soft	5
Shale.	
Dip 45° W.	

Coulterville.—A very thin seam carrying not more than 4 inches of poor ore was the only showing that could be found near this place.

Graysville.—A thin seam of iron ore with a shale parting in places was found near Graysville. The following sections indicate the thickness, character, and dip of this ore.

Section of "Rockwood" ore about 1 mile southeast of Graysville.

(Pl. II, 18, and corresponding ore section.)

	Inches.
Shale.	
Ore, soft	5
Shale	4
Ore	6
Shale.	
Dip 60° W.	
Total ore, 11 inches.	

Section of "Rockwood" ore about ¾ mile southeast of Graysville.

(Pl. II, 19, and corresponding ore section.)

	Inches.
Shale.	
Ore, soft	10
Shale	3
Ore	6
Shale.	
Dip 75° W.	
Total ore, 1 foot 4 inches.	

Section of "Rockwood" ore about ¾ mile east of Graysville.

(Pl. II, 20, and corresponding ore section.)

	Inches.
Shale.	
Ore, soft	8
Shale.	
Dip 80° W.	

Section of "Rockwood" ore 1¼ miles northeast of Graysville.

(Pl. II, 21, and corresponding ore section.)

	Inches.
Shale.	
Ore, soft	10½
Shale.	
Dip 82° W.	

Section of "Rockwood" ore 2¾ miles northeast of Graysville.

(Pl. II, 22, and corresponding ore section.)

	Inches.
Shale.	
Ore, soft	9
Shale.	
Dip 87° W.	

Section of "Rockwood" ore 3 miles northeast of Graysville.

(Pl. II, 23.)

	Inches.
Shale.	
Ore, soft	5
Shale.	
Bed stands vertical.	

Dayton.—In the vicinity of Dayton the iron ore is a little thicker than near Graysville, but it has been worked only for the soft ore on the outcrop. The following section was measured.

Section of "Rockwood" ore 1 mile southwest of Dayton near Abel Branch.

(Pl. II, 24, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, soft	1	2
Shale.		
Dip 56° W.		

Section of "Rockwood" iron ore at Dayton ½ mile northwest of blast furnace.

(Pl. II, 25, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, soft, about	1	6
Shale.		
Bed vertical.		

According to reports, the Dayton Coal and Iron Company sunk a shaft many years ago on the ore bed about one-half mile northwest of the blast furnace, and reached hard ore at a depth of about 40 feet. The hard ore measured about 1 foot 6 inches in thickness between shale walls, and stood vertical. This hard ore is reported to carry about 30 per cent metallic iron. Northeastward from Dayton there are two seams of ore in the section about 35 feet apart. Two and four miles north of Dayton the following sections were measured.

Section of lower seam of "Rockwood" iron ore 2 miles north of Dayton.

(Pl. II, 26, and corresponding ore section.)

	Inches.
Shale.	
Ore, soft	3
Shale	8
Ore	3
Shale.	
Dip 40° W.	
Total ore, 6 inches.	

Section of upper seam of "Rockwood" iron ore 2 miles north of Dayton.

(Pl. II, 26, and corresponding ore section.)

	Inches.
Shale.	
Ore, soft, vary sandy	8
Shale.	
Dip 40° W.	

Section of lower seam of "Rockwood" ore 4 miles northeast of Dayton.

(Pl. II, 27, and corresponding ore section.)

	Inches.
Shale.	
Ore, soft	4
Shale	7
Ore	4
Shale.	
Dip 45° W.	
Total ore, 8 inches.	

About 35 feet above this seam, another thin seam of ore was measured, as follows:

Section of upper seam of "Rockwood" ore 4 miles northeast of Dayton.

(Pl. II, 27, and corresponding ore section.)

	Inches.
Shale.	
Ore, soft	10
Shale.	
Dip 45° W.	

Evensville.—The two seams just described may be traced northeastward beyond Evensville. The following sections illustrate the general character of these seams in this vicinity.

Section of lower seam of "Rockwood" ore 1 mile southwest of Evensville.

(Pl. II, 28, and corresponding ore section.)

	Inches.
Shale.	
Ore, soft	7
Shale	10
Ore	3
Shale.	
Dip 25° (?) NW.	
Total ore, 10 inches.	

Section of upper seam of "Rockwood" ore 1 mile southwest of Evensville.

(Pl. II, 28, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, soft	1	3
Shale.		
Dip about 78° toward northwest.		

Section of lower seam of "Rockwood" ore 1 mile northwest of Evensville.

(Pl. II, 29, and corresponding ore section.)

Shale.	Feet.	Inches.
Ore, soft	..	7
Shale	2	..
Ore	..	3

Shale.
Dip 56° NW.
Total ore, 10 inches.

Section of upper seam of "Rockwood" ore 1 mile northwest of Evensville.

(Pl. II, 29, and corresponding ore section.)

Shale.	Feet.	Inches.
Ore, soft	1	3

Shale.
Dip 85° NW.

Section of lower seam of "Rockwood" ore 1½ miles north of Evensville.

(Pl. II, 30, and corresponding ore section.)

Shale.	Inches.
Ore, soft	6
Shale	7
Ore	5

Shale.
Total ore, 11 inches.
Dips anticlinal 30° SE. to 65° NW.

Section of upper seam of "Rockwood" iron ore 1½ miles north of Evensville.

(Pl. II, 30, and corresponding ore section.)

Shale.	Inches.
Ore, soft	11

Shale.
Dip 75° W.

The exposure of the lower of these seams shows an anticlinal fold, the east limb dipping 30° toward the southeast and the west limb 65° toward the northwest.

Section of lower seam of "Rockwood "ore 2½ miles northeast of Evensville.

(Pl. II, 31, and corresponding ore section.)

Shale.	Feet.	Inches.
Ore, semi-hard, shaly, poor quality	1	3

Shale.
Dip about 78° toward NW.

Section of upper seam of "Rockwood" ore 2½ miles northeast of Evensville.

(Pl. II, 31, and corresponding ore section.)

Shale.	Feet.	Inches.
Ore, soft	1	0

Shale.
Dips anticlinal; 25° SE. and 75° NW.

The lower seam here was prospected many years ago by a shaft about 50 feet deep, where semi-hard ore was reached. The ore is reported to have a shaly texture. The upper seam outcrops in an anticlinal fold, one limb dipping 25° toward the southeast, and the other 75° toward the northwest.

About 4 miles northeast of Evensville, within a section of 40 feet, several thin seams of iron ore, ranging from 2 inches to 9 inches in thickness were uncovered by prospecting. The ore in all cases was soft, and probably where hard would be slightly thicker. The dip of the inclosing shale is about 78° to the northwest.

Valley Areas.

Inman locality.—On the east side of Sequatchie Valley, about 9 miles above the confluence of Sequatchie and Tennessee rivers, the outcrop of the "Rockwood" formation has been found to carry ore that is workable where soft. (See Pl. III.) The beds dip at a low angle to the southeast below the Mississippian rocks at the base of Walden Ridge. At the town of Inman, now abandoned, mining operations were active for 10 or 15 years prior to 1903. The old openings were visited in 1906 and 1911, but it was impossible to enter the underground mines for any great distance owing to the badly caved-in condition of the workings. A limy ore bed, apparently about 4½ feet thick, carrying 2½ to 3 feet of good ore, was measured here in 1906, as shown in the following section:

Section of "Rockwood" iron ore at old Inman mines.

(Pl. III, 1, and corresponding ore section.)

	Feet.	Inches.
Sandstone, shaly	..	8
Ore, hard, fossiliferous with crystals of calcite	1	2
Shale, calcareous	..	2½
Ore, similar to above	..	11
Limestone	..	8
Ore, hard, good quality	..	8
Shale (base not exposed)	..	..
Ore (reported)	..	8
Shale.		

Total ore, 3 feet, 5 inches.

grading into pinkish gray crystalline limestone in places..... 6–10
Shale.
Dip 11° S. 60° E.

The lower seam here was prospected many years ago by a shaft about 50 feet deep, where semi-hard ore was reached. The ore is reported to have a shaly texture. The upper seam outcrops in an anticlinal fold, one limb dipping 25° toward the southeast, and the other 75° toward the northwest.

About 4 miles northeast of Evensville, within a section of 40 feet, several thin seams of iron ore, ranging from 2 inches to 9 inches in thickness were uncovered by prospecting. The ore in all cases was soft, and probably where hard would be slightly thicker. The dip of the inclosing shale is about 78° to the northwest.

Valley Areas.

Inman locality.—On the east side of Sequatchie Valley, about 9 miles above the confluence of Sequatchie and Tennessee rivers, the outcrop of the "Rockwood" formation has been found to carry ore that is workable where soft. (See Pl. III.) The beds dip at a low angle to the southeast below the Mississippian rocks at the base of Walden Ridge. At the town of Inman, now abandoned, mining operations were active for 10 or 15 years prior to 1903. The old openings were visited in 1906 and 1911, but it was impossible to enter the underground mines for any great distance owing to the badly caved-in condition of the workings. A limy ore bed, apparently about 4½ feet thick, carrying 2½ to 3 feet of good ore, was measured here in 1906, as shown in the following section:

Section of "Rockwood" iron ore at old Inman mines.

(Pl. III, 1, and corresponding ore section.)

	Feet.	Inches.
Sandstone, shaly	..	8
Ore, hard, fossiliferous with crystals of calcite	1	2
Shale, calcareous	..	2½
Ore, similar to above	..	11
Limestone	..	8
Ore, hard, good quality	..	8
Shale (base not exposed)	..	..
Ore (reported)	..	8
Shale.		

Total ore, 3 feet, 5 inches.

... spots and
grading into pinkish gray crystalline limestone in places..... 6–10
Shale.
Dip 11° S. 60° E.

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Section of "Rockwood" iron ore at old Inman mines.

(Pl. III, 1, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, hard, fossiliferous, with crystals of calcite	1	2
Shale	..	5
Ore	..	6
Limestone	..	6
Ore	1	..
Shale.		

Dip 6° to 8° S. 50° E.

Total ore, 2 feet, 8 inches.

More than 2,000,000 long tons of ore are reported to have been shipped from the Inman mines, principally to the now abandoned blast furnaces of the Tennessee Coal, Iron and Railroad Company at South Pittsburg, Tenn. The surface workings extended for 2 miles along the outcrop and for more than 500 feet underground. Apparently but little ore can be considered to be available under present conditions in this area. It is possible that with the future exhaustion of the supplies of higher grade ore throughout the United States the hard ore in this locality may again be considered of value, but it will probably be only in the remote future. From such information as is available it seems that the hard ore carries between 22 and 28 per cent, averaging about 24.5 per cent of metallic iron, and an average of 30.7 per cent of lime. Of course the quantity of ore present in this locality, without reference to its availability or quality, is very great if it be considered that the ore possibly extends on the dip all the way below Walden Ridge from Inman to the eastern outcrop near Williams Island, a distance of some 10 miles. The depth below the outcrop in the middle of this basin would probably be 750 to 900 feet along Tennessee River between McNabb and Stanley,—not a prohibitive distance to drill, if it should be desired to test the ore in this basin.

A few miles north of the old Inman mines the following section was measured:

Section of "Rockwood" iron ore near Ketner's Mill.

(Pl. III, 2, and corresponding ore section.)

	Inches.
Shale.	
Limestone, greenish, hard, fossiliferous, ferruginous in places, about	8–10
Ore, hard, fossiliferous, and oolitic; rich in iron in spots and grading into pinkish gray crystalline limestone in places	6–10
Shale.	

Dip 11° S. 60° E.

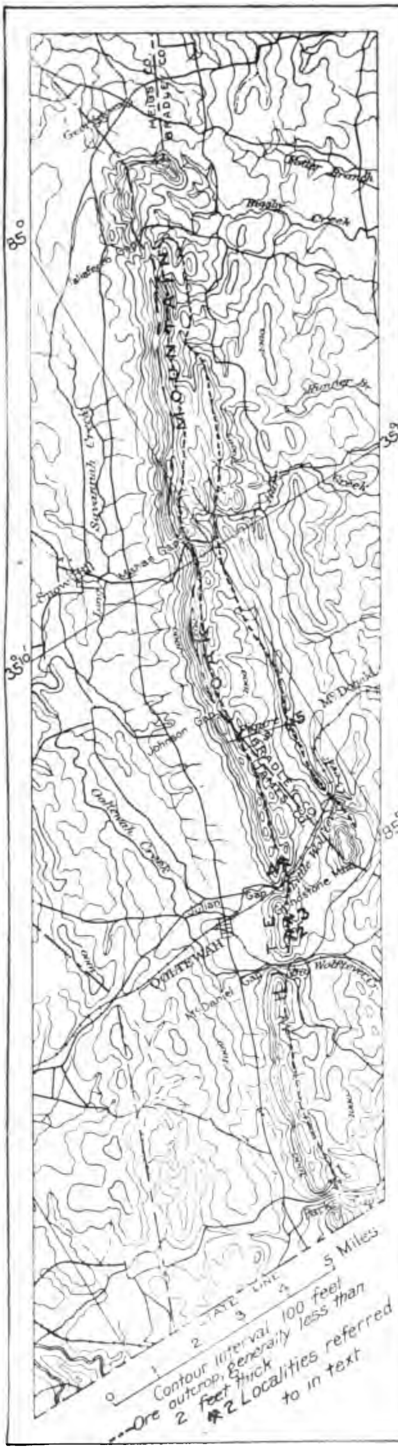


FIGURE 12.—Topographic map showing outcrop of "Rockwood" iron ore bed near Ooltewah. (Base from U. S. Topographic atlas sheets.)

Whiteoak Mountain.—Several examples of ore-bearing synclines on a smaller scale than those of Walden Ridge and Lookout Mountain are afforded in East Tennessee. One of these is Whiteoak Mountain, about 15 miles east of Chattanooga. (See map Fig. 12.) The "Rockwood" formation on the northwest limb of this syncline dips southeast at a moderate angle, but the southeast limb is faulted and overturned, so that such ore beds as are present there are badly shattered, crumpled, and steeply inclined, and for some miles are entirely buried in the fault. The relations of the strata in Whiteoak Mountain are shown in the structure section, Fig. 13. This narrow syncline enters the State at its southern border and extends northeastward for 20 miles, the synclinal axis gradually rising so that at its northeast extremity the beds have been eroded to a feather edge and finally disappear. From the State line northeast nearly to McDaniel Gap the ore seams are very thin. A section was measured in Parker Gap near the Tennessee-Georgia State line as follows:

Section of "Rockwood" ore in Parker Gap near Hurricane Creek.

(Fig. 12, 1.)

	Inches.
Shale.	
Ore, soft, excellent quality	6
Shale.	
Dip 35° NE.	

In the vicinity of Ooltewah the "Rockwood" formation contains several thin seams of iron ore. These seams outcrop on both sides of the

syncline, the edges of which are exposed in Whiteoak Mountain, and in a smaller parallel ridge lying about 2 miles farther east. The lower part of the formation here consists largely of hard, brown sandstone, but the upper part contains considerable shale. Ore is present in the shale on the east slope of Whiteoak Mountain the beds dipping 22° to 25° to the southeast. The ore is a compact, deep, red material with flattened grains mingled with fragments of crinoid stems all consisting of nearly pure hematite. The ore beds do not dip uniformly, there being many minor crumplings in the strata that cause the dip to vary considerably and make mining uncertain and difficult. The ore ranges from 5 to 18 inches in thickness, and in places includes streaks of shale. Twenty-five years ago soft ore was obtained in large quantities from surface workings northeast and southwest of the cuts of the Southern Railway through Julian Gap and McDaniel Gap, and was shipped to the blast furnaces at Chattanooga. At present, however, no ore for blast furnace use is obtained here. Shallow underground workings are operated intermittently by hand for the purpose of obtaining ore for the manufacture of metallic paint. The paint ore is mined from slopes and short drifts driven along the strike of the bed with rooms turned up and down the dip. The main openings—mostly less than 30 inches in height—are high enough only to admit a shallow push car, and the miners must crawl in on hands and knees and work in a sitting posture. Few of the rooms are timbered, but the roof over the main entry is in most places supported by posts. Few of the workings extend underground more than 100 feet. Southeast of Wells Switch several small mines were operated when this locality was visited in 1906, and the following two sections were measured:

Section of "Rockwood" iron ore mined for paint, 1 mile south of Julian Gap, Whiteoak Mountain.

(Fig. 12, 2, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, solid, well leached, fossiliferous	1 to 1	4 to 6
Shale.		
Dip about 22° S. 65° E.		

Section of "Rockwood" iron ore ¾ mile south of Julian Gap, Whiteoak Mountain.

(Fig. 12, 3, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, solid, rich red, fossiliferous	1	2
Shale	3–4	..
Ore (not mined)	..	3 to 4
Shale.		
Dip 23° toward southeast.		
Total ore, 1 foot, 6 inches.		

North of Wells Switch ore was being worked in 1906 in a small drift with upshoots. The ore bed here varies in thickness, thinning down from 14 to 5 inches, owing to a squeeze in the overlying shale. The average thickness is only about 10 inches, yet it seems possible to mine for paint ore a bed as thin as this where there is but a short wagon haul to the railroad. A second seam of ore 6 to 7 inches thick occurs 3 feet lower, but is not mined. The following section shows the character and relation of these seams:

Section of "Rockwood" iron ore on Whiteoak Mountain, ¼ mile north of Wells Switch.

(Fig. 12, 4, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, solid, rich red, fossiliferous and granular, mined for paint	..	5 to 10
Shale	3	..
Ore, similar to above	..	6 to 7
Shale.		

Dip 26° S. 60° E.

Total ore, 11 inches to 1 foot 5 inches.

In the valley east of Whiteoak Mountain, between Big and Little Wolfclever creeks, considerable "Rockwood" ore in the form of lumps and well rounded pebbles derived from the disintegration of the ore beds has been washed down the gullies, and they have been gathered from time to time and sh pped to paint manufacturers.

In the ridge on the east limb of Whiteoak Mountain syncline near Hinch's Switch on the Southern Railway, red ore outcrops apparently in two beds of about the same thickness, but geological examination has shown that this effect has been produced through the outcrop of a single bed of ore having been repeated by a closely compressed overturned anticline, the crest of which has been removed by erosion. This relation is shown in the structure section, Fig. 13.

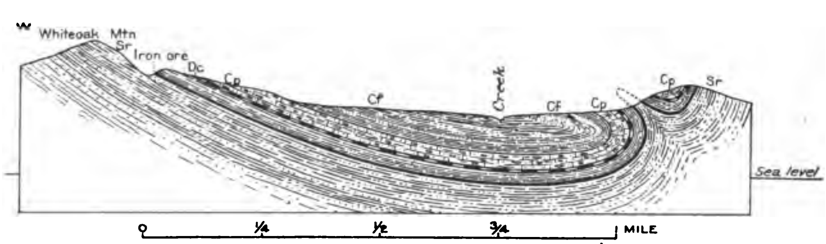


FIGURE 13.—Northwest-southeast structure section across Whiteoak Mountain syncline northeast of Ooltewah.

Sr, "Rockwood" formation.
Dc, Chattanooga shale.
Cp, Fort Payne chert.
Cf, Floyd shale.

Locally the same bed is displaced and repeated by an overthrust fault, and 1 mile south of Hinch's switch the entire "Rockwood" formation on the east limb of the syncline has been buried in a fault. The ore north of the railroad in this ridge averages about 12 inches in thickness, although in places it reaches 16 to 20 inches. Within the seam are a few partings of shale. The following section shows the general character of this ore seam.

Section of "Rockwood" iron ore, 1½ miles north of Hinch's Switch.

(Fig. 12, 5, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, firm, rich red, fossiliferous and granular, parted in places by wedge of shale 1 to 10 inches thick; ore averages 1 ft. thick	1	10 to 4
Shale.		
Bed lies nearly horizontal in trough of syncline.		

From Hinch's Switch northward for about 4 miles soft ore was stripped for iron making in former years. At present the ore is mined for paint from underground drifts and shallow slopes at several points in this vicinity, and the product is shipped to Chattanooga.

The ore that is mined for paint in this synclinal basin, is for the most part of the soft variety, that is, the original content of lime carbonate has been removed by solution, yet the ore is so firm that it has to be blasted out. It is probable that the lime carbonate was originally lower than that of the hard ores of the Cumberland escarpment. The siliceous content of the ore if of moderate percentage is of advantage as it acts as an extender of the dry color when the ore is ground to a powder.

Analyses of the Ooltewah ore are given on page 108.

As to the relation of this ore to the iron industry it might be stated that in order to bring the cost of production within the limits of the market prices of ore for blast furnace use, mining must be conducted on a scale involving the use of power, cables, and general mine equipment, and all rail haulage, involving the construction of one or two railroad spurs a mile or more in length, would be required. The total amount of ore in sight in the Whiteoak syncline indicates that the beds would be exhausted too soon to warrant this outlay. Furthermore, the beds are so thin that a larger quantity of shale than ore would have to be removed, either to win the ore or to provide the head room necessary for regular mining work, thereby rendering it doubtful whether the ore could profitably be worked for iron, even if the quantity in sight were sufficient. When the right kind of ore occurs under these conditions it is sufficiently valuable to paint manufacturers to bear the cost of mining by hand and of haulage by wagon to the nearest railroad. Ordinary grades of iron ore, such as are smelted in the district are not suitable for paint manu-

facturing, and therefore they cannot compete with the more expensive material here considered, although a small amount of high grade ore that would otherwise be smelted is sold by the iron producers to paint manufacturers on account of the good price it commands.

Most of the ore from the vicinity of Ooltewah is ground by mills at Chattanooga, but a part of it goes at times to Birmingham, Alabama. The paints made are the reds and dark browns, and a considerable quantity of the ground oxide is sold for coloring sand-lime bricks and mortars for pressed brick and concrete work.

Resume.—Sections and Analysis.

The leading facts presented above with regard to the "Rockwood" iron ore beds outcropping in southeast Tennessee may be briefly reviewed here. Perhaps the most important question with regard to a bed of ore at a given place is its thickness. Next, provided the bed is of a workable thickness, is the question of quality, and third is the question of extent. With reference to the third question, it may be said that "Rockwood" ore outcrops all the way along the foot of Cumberland escarpment, with the exception of about 6 miles in the vicinity of Daisy almost continuously from the Georgia line to northeast of Evensville a total length of about 45 miles. In addition to this length of outcrop there are 25 miles of outcropping ore measures brought to the surface by anticlinal and synclinal folds near Chattanooga. In places two to four thin seams of ore occur. The thickness of the ore in some areas is less than 2 feet, and there are certain places where there are more than 2 feet of ore in the section, as indicated on the map Pl. II. In the cut of the N. C. & St. L. Ry. 2 miles west of Wauhatchie (Pl. II, 1) there is a total of 3 ft. 7½ in. of ore in a section of ore and shale aggregating 5 ft. 2 in. thick. Most of this ore is little more than ferruginous limestone, but southwestward in Georgia the ore bed becomes richer. One-fourth mile east of Williams Island (Pl. II, 9) the bed showed 2 feet 4 inches of hard calcareous ore. Near Falling Waters within a section of 27 feet 6 inches there are 5 feet 3 inches of lean ore, no single bed of which is thicker than 1 ft. 1 inch. The outcrops at Hill City showed 2½ feet to more than 3 feet of ore with one shale parting 2 to 7 inches thick near the middle. The hard ore is lean and calcareous, but there is still some soft and semi-hard ore here. The "Rockwood" formation at Hill City has a very irregular structure. The beds are considerably faulted and so closely folded as to make deep or extensive mining very difficult. Near Daisy a section showed 2 feet 7 inches of ore within 8 feet 2 inches of shale and ore. In the Sequatchie Valley near Inman there is a strip of indefinite length, probably not exceeding 5 miles, in which a limy ore bed outcrops with a thickness of 2½ to 3½ feet.

Soft ore mining was carried on extensively at Hill City and at Inman many years ago. Whether mining activities are ever renewed in these localities or elsewhere in Tennessee near Chattanooga will depend on future conditions in the iron industry. For the present, ore to supply furnaces at Chattanooga will probably be obtained from areas farther north in Tennessee and from northeastern Alabama and northwestern Georgia fields.

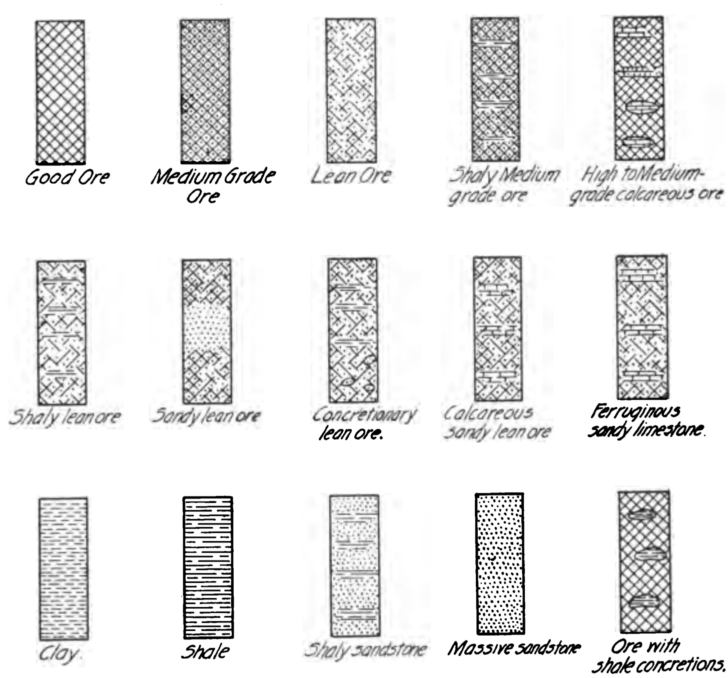


FIGURE 14.—Explanatory key to iron ore sections.

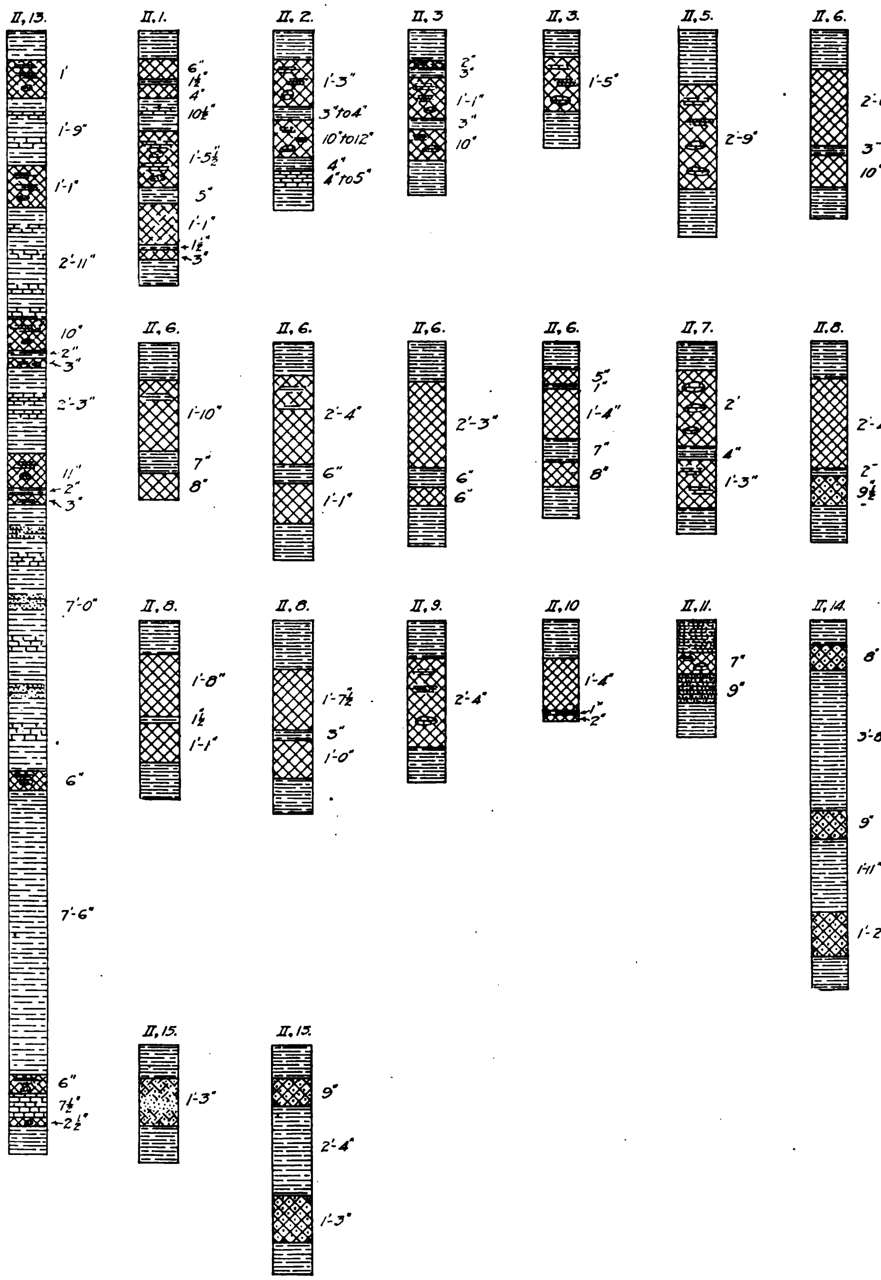


FIGURE 15.—Graphic sections of "Rockwood" iron ore beds, southeast Tennessee.

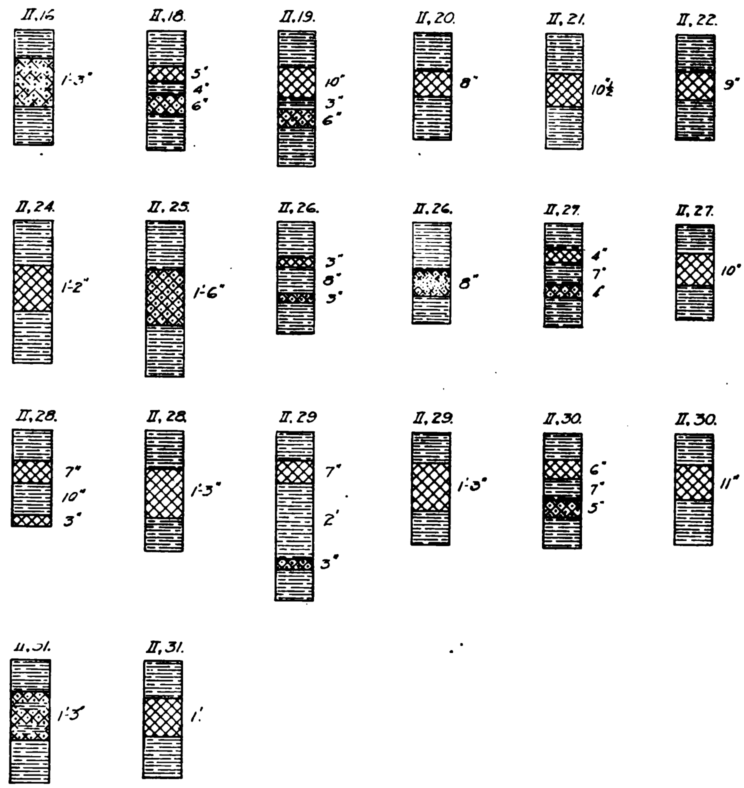


FIGURE 16.—Graphic sections of "Rockwood" iron ore beds, southeast Tennessee (Continued).

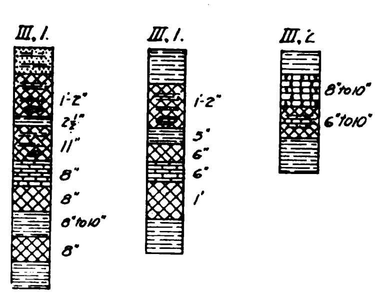


FIGURE 17.—Graphic sections of "Rockwood" iron ore beds near Inman.

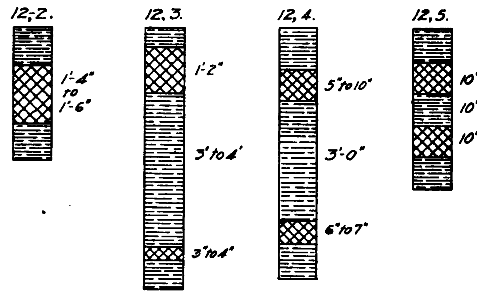


FIGURE 18.—Graphic sections of "Rockwood" iron ore beds near Ooltewah.

In the following figures and tables are given graphic sections of the ore beds in Southeast Tennessee and chemical analyses of iron ore from several localities.

Analyses of "Rockwood" iron ore, Southeast Tennessee.

Locality.	Authority.[1]	Fe	SiO_2	Al_2O_3	CaO	MgO	Mn	P	S	H_2O
Near Williams Island, Pl. II (8 1)	US	11.72	......	......	......	......	......	......	......	......
Hill City, upper bench, Pl. II (8 7a)	US	27.30	6.21	3.20	26.53	......	0.056	(P_2O_5) 0.52	0.068	......
Hill City, lower bench	US	17.27	......	......	......	......	......	......	......	......
Falling Waters Cr. middle bed 13 in. thick., Pl. II (8–9c)	US	12.53	......	......	......	......	......	......	......	......
Hill City,										
Hard ore	R	25.00	[2]11+	......	......	......	......	......	......	......
Soft ore	R	45+	[2]24+	......	......	......	......	......	......	......
Do	R	37.86	[2]22.23	......	......	......	......	......	......	......
Do	O	57.5	10.26	1.61	0.50	......	0.46	0.432	......	3.45
Ooltewah,										
Soft ore	B	56.00	16.45	......	......	......	......	.28	.10	......
Do	B	48.36	14.78	......	......	......	......	.63	......	......
Inman,										
Hard ore	B	27.93	7.07	......	18.11	......	......	2.82	......	......

[1]Authorities: US, U. S. Geol. Survey· R, Roane Iron Co.; O, Owners; B, W. M. Bowron.
[2]Insoluble.

CENTRAL EAST TENNESSEE.

Cumberland Escarpment Area.

The area between Sheffield on the southwest and Coal Creek on the northeast contains, near its middle portion, the red ore deposits that are at present the most important in the State, and it has been included in a single map. (See Pl. IV.) This area is comprised mainly within the Kingston and Briceville quadrangles, but crosses the northwest corner of the Loudon quadrangle. All these quadrangles are covered by United States Geological Survey folios. In the vicinity of Sheffield the ore is not particularly valuable, according to the sections measured in the summer of 1911, and from Sheffield northeast to beyond Glen Alice

the ore can hardly be characterized as workable underground under present conditions, but from Rockwood to Cardiff the ore is relatively thick and of good quality. Northeast of Harriman the ore becomes thin and irregular in quality, and in several places is cut out for long distances by faults.

Sheffield.—Near Sheffield there are several seams in the "Rockwood" formation in which the iron oxide sediments range from 6 to 7 inches to possibly two feet in thickness. The descriptions of some of these sections follow:

Section of "Rockwood" iron ore (lower seam) 1 mile southwest of Sheffield.
(Pl. IV, 1, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, semi-hard	..	4
Shale	..	2
Ore	1	9
Shale.		
Dip 65° W. Total ore, 2 feet 1 inch.		

Section of "Rockwood" iron ore (upper seam) 1 mile southwest of Sheffield.
(Pl. IV, 1, and corresponding ore section.)

	Inches.
Shale.	
Ore, soft	11
Shale.	
Dip 45° W.	

Section showing 5 seams of "Rockwood" iron ore 1¼ miles northwest of Sheffield.
(Pl. IV, 2, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Top or fifth seam (total ore 1 foot 1 inch):		
Ore, soft	..	6
Shale	3	6
Ore	..	7
Shale	35	..
Fourth seam (total ore, 2 feet):		
Ore, soft	1	1
Shale	1	2
Ore, soft	..	11
Third seam:		
Shale	60	..
Ore, soft	..	11
Shale	24	..
Second seam:		
Ore, soft	..	4
Shale	12	..
First seam:		
Ore, soft	..	5
Shale.		
Dips range from 60° to 65° toward west.		

Spring City.—In the vicinity of Spring City the following sections were measured.

Section of "Rockwood" ore 1 mile northwest of Spring City.

(Pl. IV, 3, and corresponding ore section.)

	Inches.
Shale.	
Ore, soft	7
Shale	2
Ore	11
Shale.	

Dips 55° west.
Total ore, 1 foot 7 inches.

Section of "Rockwood" ore 1¼ miles northwest of Spring City.
(Lower seam.)

(Pl. IV, 4, and corresponding ore sections.)

	Feet.
Shale.	
Ore, soft	2
Shale.	

Dip 55° northwest.

Section of "Rockwood" ore 1¼ miles northwest of Spring City.
(Upper seam.)

(Pl. IV, 4, and corresponding ore section.)

	Inches.
Shale.	
Ore, soft	7
Shale	2
Ore	11
Shale.	

Dip 50° W.
Total ore, 1 foot 7 inches.

Section of "Rockwood" ore 2 miles northwest of Spring City.

(Pl. IV, 5, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, soft, dark, containing some disseminated shaly matter, ore is slickensided and breaks into plates and small blocks	1	7
Shale.		

Dip steep toward northwest.

Section of "Rockwood" ore 2 miles northwest of Spring City.

(Pl. IV, 5, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, including several shaly partings 1 to 5 inches thick	2	9
Shale.		

Dip about 35° E.
Total ore about 2 feet.

The ore in this section has been overturned by folding. It may represent the seam whose section is shown next above, the apparent increase in thickness possibly being due to a "roll," following a "squeeze" in the ore.

Section of "Rockwood" ore 2½ miles northwest of Spring City.

(Pl. IV, 6, and corresponding ore section.)

	Feet	Inches
Shale.		
Ore, soft, heavy, lustrous, fossiliferous, and finely granular	1	7
Shale	..	1
Ore	..	2
Shale	..	1
Ore, argillaceous near base	..	7
Shale.		

Dip steep southeast.
Total ore, 2 feet 4 inches.

Section of "Rockwood" ore 4 miles north of Spring City (upper seam).

(Pl. IV, 7, and corresponding ore section.)

	Inches.
Shale.	
Ore, soft	3
Shale	1½
Ore	7
Shale.	

Dip 45° W.
Total ore, 10 inches.

Roddy and Glen Alice.—Between Spring City and Roddy a fault has dropped the Carboniferous formations down against the Knox dolomite, burying deeply the "Rockwood" formation. From about one-half mile west of Roddy a strip of the "Rockwood" formation extends northeastward about 5 miles where it is again cut off by a block of coal measure rocks which has been faulted down transverse to the strike. This strip of the "Rockwood" is bounded on the east for about 3½ miles by a block of coal measure rocks which have been faulted against it. The following seven sections were measured in the ore of this strip. The ore is very thin southwest of White Creek.

Section of "Rockwood" ore one-half mile west of Roddy.

(Pl. IV, 8.)

	Inches.
Shale.	
Ore, soft	3 to 4
Shale.	

Dip 65° NW.

Section of "Rockwood" ore 2 miles southwest of Glen Alice (lower seam).
(Pl. IV, 9, and corresponding ore section.)

	Inches.
Shale.	
Ore, soft	5
Shale.	
Dip 50° W.	

Section of "Rockwood" ore 2 miles southwest of Glen Alice (upper seam).
(Pl. IV, 9, and corresponding ore section.)

	Inches.
Shale.	
Ore, soft	10
Shale.	
Dip 50° W.	

Section of "Rockwood" ore three-fourths mile west of Glen Alice.
(lower seam).
(Pl. IV, 10, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, soft	2	..
Shale	..	4
Ore	..	8
Shale.		
Dip 50° toward northwest.		
Total ore, 2 feet 8 inches.		

Section of "Rockwood" ore three-fourths mile west of Glen Alice (upper seam).
(Pl. IV, 10, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, soft	2	2
Shale.		
Dip 45° W.		

Section of "Rockwood" ore three-fourths mile west of Glen Alice (upper seam).
(Pl. IV, 10, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, soft	1	..
Shale	..	2
Ore	..	11
Shale.		
Dip 50° W.		
Total ore, 1 foot 11 inches.		

Section of "Rockwood" ore three-fourths mile northwest of Glen Alice.
(Pl. IV, 10, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore	1	7
Shale	..	2
Ore	..	2
Shale.		
Dip steep to southeast, overturned.		
Total ore, 1 foot 9 inches.		

Rockwood and Cardiff.—From Rockwood to beyond Cardiff the "Rockwood" formation forms generally a low ridge or line of foothills in front of the Cumberland escarpment. The beds dip to the northwest, passing below the Mississippian chert and limestone, which in turn are overlain in the Cumberland escarpment by masses of sandstone, shale, and beds of coal. Underlying the "Rockwood" formation to the southeast is the Chickamauga limestone, below which lies the Knox dolomite, underlain by shale and sandstone of Cambrian age. The "Rockwood" here contains one bed of ore which is workable between Rockwood and Harriman; also at a few points south of Rockwood as far as Glen Alice. The normal thickness of the ore bed ranges from 2½ to 4 feet. The degree of dip of the "Rockwood" rocks and their enclosed ore beds varies greatly from place to place along the outcrop, and it is not at all uniform at right angles to the outcrop. In places the bed at the outcrop dips very steeply 75° to 80° NW. Where followed underground for distances of 20 to 100 feet along the dip, it may be found to be faulted and offset several feet. Commonly the broken edges of the bed have been shoved past each other so as to overlap, giving the impression that there are two beds of ore in the section. The dip of the ore beyond such a fault generally grows less until the bed is nearly flat, and in places the dip is reversed so that the bed rises to the northwest. Beyond such a rise, the bed is usually found to pitch steeply or vertically down for 40 to 60 feet and then to flatten again, and so on. A series of such folds has been recognized in the area between Rockwood and Cardiff (see Fig. 19), and some of them

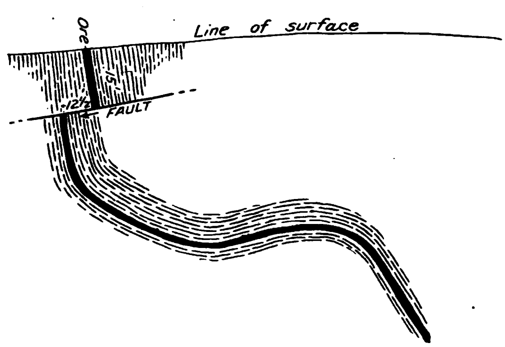


FIGURE 19.—Profile section showing fault folds in bed of "Rockwood" iron ore near surface in Cardiff mine.

are overturned so as to dip toward the southeast. From crest to crest the distances range between 40 to 100 feet, and in height the folds range from 15 to 60 feet. There is some variation in the strike of the beds, due to the fact that the axes of the folds are sinuous and, instead of lying flat, plunge at a low angle to the southwest. As a result of the plica-

tions in the strata, the ore bed has been squeezed in places to less than its normal thickness, and in others it is swelled to more than its nornal thickness. The thickest portions occur generally along the axes of the troughs or at the tops of the arches. Where the bed is pinched down, it may be less than 18 inches in thickness; in the thickened places as much as 6.25 to 8 feet of ore has been observed. There are reasons for believing that this folding took place below a great thickness of cover. The fact that movement has taken place between the particles of ore is plainly shown by the slickensided condition of ore fragments. The ore is also minutely jointed. Since the close folding took place the superincumbent beds have been largely removed by erosion and later adjustment of stresses has resulted in the faulting and overthrusting of beds near the surface.

Between Rockwood and Cardiff the normal thickness of the ore ranges from 2½ to 4 feet, including a few local shale partings or lenses one-half to 1 inch thick. The ore is fossiliferous red hematite. In places it is somewhat granular, resembling oolitic ore. On the outcrop and near the surfacethe ore is "soft," the lime having been dissolved out; but below cover it is "hard" and contains lime. The soft ore has nearlyall been mined from the outcrop by stripping and trenching and from shallow drifts. The hard ore now being mined carries 33 to 40 per cent of iron, 6 to 15 per cent of silica, 4 to 8 per cent of alumina, 10 to 17 per cent of lime 2.5 to 3.5 per cent of magnesia, 0.15 to 0.3 per cent of manganese, 0.5 to 0.6 per cent phosphorus, 0.015 to 0.2 per cent of sulphur, and 1.8 to 4 per cent of water. The specific gravity of the hard ore, as determined at the laboratories of the Roane Iron Company, ranges from 3.29 to 3.36, which corresponds to 10.9 and 10.68 cubic feet per ton of 2,240 pounds. South of Rockwood the ore becomes thinner, a bed 15 to 30 inches thick having been worked on the outcrop and from shallow drifts near Spring City and Glen Alice.

The principal mining development in this area is along a strip extending from Rockwood northeastward to Emory Gap, a distance of about 7½ miles. On this strip there are eight slope mines in operation and about the same number of inactive slopes. The slopes vary in length from a few hundred feet to 1,200 feet. They are not driven so as to follow the ore, a course that would be physically impossible, owing to the folding of the beds. The slopes are consequently driven in rock below the ore at a pitch of 28° to 32° in a westerly direction, diagonal to the directions of both dip and strike of the ore bed. At intervals of 100 feet entries or "lifts" are turned off through the rock so as to intersect the ore from the footwall side. From each lift air ways or rooms are turned up to the lift above, a vertical distance of 30 feet, leaving a pillar of 20 feet between the rooms. Most of the ore finally is robbed from

the pillars. Drilling is done by hand machines as they have proved more satisfactory than power drills. Mining under these structural conditions is difficult, but has been so well systematized here that very little ore is lost. The mines from Rockwood to Cardiff are operated by the Brown Mining Company, which supplies ore to the two furnaces of the Roane Iron Company, at Rockwood, the owner of the ore lands, besides shipping some ore to the Citico Furnace at Chattanooga.

No prospect drilling has been done between the ends of the present slopes and the escarpment of Walden Ridge, so that the character of the ore beyond the present workings is unknown. Apparently there has been no diminution in the thickness of the beds at right angles to the outcrop so far as explored, and it is probable that the ore bed extends northwestward under the coal field to distances and depths too great for mining. It is understood that some of the present inactive slopes have been driven about to the limit of profitable mining under present conditions. To judge from the dip of the coal beds in the Cumberland Plateau, the ore should become less steep and less sharply folded beyond the line where it passes beneath the coal measures, and therefore it is possible that conditions would be favorable for the extraction of ore from beneath the Cumberland area. As to the continuity of the ore for great distances below the coal measures, it may be stated that the "Rockwood" formation either is wholly absent or is very thin and does not carry workable ore in the north end of the anticlinal Sequatchie Valley opposite Spring City. Conditions observed in many other "Rockwood" areas indicate that the ore deteriorates more abruptly in the direction of the dip than along the outcrop.

The following nine sections were measured at places between Rockwood and Cardiff:

Section of "Rockwood" ore at north end of tunnel in second "lift" Patton slope, 1½ miles northeast of Rockwood.

(Pl. IV, 8, and corresponding ore section.)

Shale.	Feet.	Inches.		Feet.	Inches.
Ore	2	8	to	2	10
Shale, with streaks of ore in middle	..	8	to	..	9
Ore	..	..		..	3
Shale	..	..		..	1
Ore	..	..		..	2
Shale	..	..		..	1
Ore	..	..		..	3
Shale.					

Bed stands vertical. Strike N. 65° E.

Total ore, 3 feet 6 inches.

Section of "Rockwood" ore at south end second lift, Patton slope.
(Pl. IV, 18, and corresponding ore section.)

Shale.	Feet.	Inches.
Ore	..	2
Ore, shaly	..	6
Ore, good quality	2	9
Ore, shaly	..	7

Shale.
Dip 40° S. 30° W.
Total ore, 3 feet 6 inches.

Section of "Rockwood" ore at north entry seventh lift, Patton slope.
(Pl. IV, 18, and corresponding ore section.)

Shale.	Feet.
Ore	4

Shale.
Bed stands nearly vertical. Strike N. 50° E.

Section of "Rockwood" ore on south end eighth lift, Patton slope.
(Pl. IV, 18, and corresponding ore section.)

Shale.	Feet.	Inches.
Ore, with a few seams of shale locally developed in upper half	4	2

Shale.
Dip 20° N. 55° W.

Section of "Rockwood" iron ore at outcrop of ore bed at Cardiff mine.
(Pl. IV, 21, and corresponding ore section.)

Shale.	Feet.	Inches.
Ore, soft, with 3 shale streaks, 1/8 to 1/2 inch thick	5	6

Dip 75° N. 10° W.

Section of "Rockwood" ore, right hand "duck's nest" 150 *feet from slope, Cardiff mine.*
(Pl. IV, 21, and corresponding ore section.)

Shale.	Feet.	Inches.
Ore	..	6½
Shale, with concretions	..	3½
Ore	..	6
Shale, with concretions	..	3 to 4
Ore, shaly near top	3	..

Shale, hard, flinty, with concretions.
Total ore, 4 feet, ½ inch.

Section of "Rockwood" ore, right hand "duck's nest" 150 *feet from slope. Cardiff mine.*
(Pl. IV, 21, and corresponding ore section.)

Shale.	Feet.	Inches.
Ore	..	3
Shale, with concretions	..	2 to 3.
Ore, with two thin partings of shale in lower half	3	9

Shale, hard with concretions.
Total ore, 4 feet.

Section of "Rockwood" iron ore in right hand "duck's nest," Cardiff mine.

(Pl. IV, 21, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, hard, with a few shale lenses ½ to 1½ inches thick	6 to 6	6
Shale.		
Dip steep, N. 30° W.		

Section of "Rockwood" iron ore in new No. 4 slope, 300 feet from drum, Cardiff mine.

(Pl. IV, 21, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, hard, with bright, steely luster, much fractured and slickensided, carrying a few kidney-shaped lenses of shale	6 to 8	3 to 0
Shale.		

Emory Gap.—Northeast from Cardiff to Emory Gap iron ore has been mined all along the outcrop and from 5 to 6 slopes, most of which are now inactive. The ore thins from an average of nearly 4 feet near Cardiff down to less than 3 feet at Emory Gap.

At Emory Gap a fault buries the "Rockwood" formation for a distance of 2½ miles to the northeast, and its next appearance in this direction is at a point about 1 mile north of the center of Harriman. From this latter point the formation may be traced northeast about 5 miles, or to a point 1½ miles northeast of DeArmond. All the outcrop, discussed above, from 4 miles southwest of Evensville to DeArmond is comprised within the Kingston quadrangle, and the general geologic relations are shown in the Kingston geologic folio (No. 4) of the U. S. Geological Survey.

Harriman.—North of Harriman the "Rockwood" formation has been somewhat broken up by folding and faulting of the strata. One seam of ore was measured in some old soft ore diggings, with the following results:

Section of "Rockwood" ore 1¾ miles north of Harriman.

(Pl. IV, 27, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, soft	2	4
Shale.		
Dip 72° N.		

Section of "Rockwood" ore 1½ miles northeast of Harriman.

(Pl. IV, 28, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, soft	1	4
Shale.		
Dip about 70° NW.		

In this vicinity considerable open cut mining of the soft ore has been done in former years, the cover having been stripped to a depth of 8 to 10 feet, after which the trenches were back-filled with shale, thus burying the ore bed and making it very difficult to find exposures.

DeArmond.—One section was measured about 1 mile northeast of DeArmond station, in the northwest corner of the Loudon quadrangle. A short distance beyond this section the outcrop of the "Rockwood" formation at the base of Walden Ridge is cut off by a fault. The section is as follows:

Section of "Rockwood" ore 1 mile northeast of DeArmond.

(Pl. IV, 29, and corresponding ore section.)

Shale.	Inches.
Ore, soft	5
Shale	2
Ore	3
Shale	1
Ore	2
Shale.	
Dip about 60° SE.	
Total ore, 10 inches.	

Northeast of the point where this ore is faulted out, there are no further outcrops of ore for nearly 6 miles, except a very small area near Elverton, which is bounded by faults. About 1½ miles southeast of DeArmond there is another narrow strip of "Rockwood" formation bounded by faults on the north and east, and regarded as of very limited extent. At the base of Cumberland escarpment the next area to the northeast lies between Scandlyn and Oliver Springs.

Oliver Springs.—The outcrop area of "Rockwood" formation next southwest of Oliver Springs does not give promise of producing any ore so far as surface appearances are concerned. This area as shown on the geologic map in the Briceville folio begins 1¼ miles southwest of Oliver Springs and extends southwest 1⅞ miles in the foothills of Walden Ridge. A brief examination was made of this area and inquiries were made of several residents. The only ore that could be found was one seam 4 to 6 inches thick, besides one thin streak measuring 1 to 1½ inches thick, which appraently forms the cap of an argillaceous sandstone. (See Pl. IV, localities 30 and 31.) The seam measuring 4 to 6 inches thick is hard and lean, and is apparently high in silica and alumina. The ore is granular and contains fragments of fossils. West of the wagon road the slope is largely covered by sandstone debris from Walden Ridge, and this debris also overlies the road in places. Some prospecting has been done in this area within the memory of the residents interviewed and no ore thicker than 6 inches was reported to have been found.

Possibly the cover of sandstone debris has deterred prospecting It appears probable that if there is a thicker bed in this area it occurs higher stratigraphically than the seam noted and lies farther west toward Walden Ridge, and is consequently covered by sandstone debris. Some prospecting has been done in the dark red sandstone and shale of the Rome formation, which lies to the southeast of the "Rockwood" area. Some of the beds in the Rome formation are rather ferruginous and of a bright red color, and are very apt to mislead persons seeking iron ore. The sandstone is of fine quartz, grains cemented loosely by iron oxide, which also coats some of the quartz grains, giving the material the appearance of an iron ore. Possibly the iron oxide might reach 10 per cent in places, but the remainder is mainly silica.

West of Clinton.—The next area to the northeast separated from the Oliver Springs locality by a distance of about 8½ miles in which the "Rockwood" beds are completely buried, lies about 5 miles due west of Clinton. The outcrop of "Rockwood" formation here is narrow, and the beds are steeply tilted and overturned so that for the most part they have southeast dips. There are two or three seams of ore in the formation here that are too thin to be of any importance, ranging from three to eight inches in thickness One ore bed, probably the lowest one noted, shows a total thickness of 24 to 27 inches of ore parted by thin shale. The following sections were measured:

Section of "Rockwood" ore 5 miles west of Clinton.

(Pl. IV, 33, and corresponding ore section.)

	Feet.	Inches.	Feet.	Inches.
Shale.				
Ore, argillaceous and limy	..	..	..	2 to 3
Ore	..	..	..	3
Ore, with nodules of lime and siliceous matter	..	..	..	2½
Ore, with a few thin lenses of shale, locally developed	1	6 to	1	7
Shale.				

Dip 32° S. 50° E.

Total ore, 2 feet 1½ inches.

This measurement was made in a fresh prospect at the south side of a small creek on the west base of one of the foothills of Walden Ridge. A small sawmill was operated on this creek just above the prospect at the time of visit.

About five-eighths mile southwest of the sawmill along the wagon road a weathered outcrop apparently of the same bed shows according to the following section:

Section of "Rockwood" ore 5¼ miles west-southwest of Clinton.

(Pl. IV, 32, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, badly weathered with several thin shaly partings......	2	3½
Shale.		
Dip 55° nearly east.		
Total ore, about 2 feet.		

Above this seam there are thin streaks of limonite and argillaceous ore within two or three feet.

Section of "Rockwood" ore 5 miles west-northwest of Clinton.

(Pl. IV, 34, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Limestone, hard, fossiliferous, and ferruginous............	..	5
Ore, soft and decomposed..............................	..	4
Shale..	..	6
Ore, hard, granular, fossiliferous, and slickensided..........	1	8
Shale.		
Dip 32° S. 45° E.		
Total ore, 2 feet.		

This measurement was made in an old prospect trench about ⅞ mile north of the sawmill where it is reported that ore was mined on the outcrop many years ago, and reduced in an old water forge on Poplar Creek 4 miles to the south.

The total length of outcrop of the ore-bearing formation in this strip west of Clinton is about 4½ miles, and it is cut off by the same fault to the northeast and to the southwest. The distance northeastward to the next outcrop of ore-bearing formation, which lies east of Briceville and south of Coal Creek, is about 1¾ miles.

Coal Creek.—South of Coal Creek at the base of Walden Ridge and east of Briceville, the "Rockwood" area is bounded on the east by the great Coal Creek fault, which cuts out these beds between Coal Creek and Caryville, and also to the southwest of Coal Creek. In part of this area the lower beds of the "Rockwood" are buried by the fault, but the upper or ore-bearing portion is present. (See structure sections Figs. 20 and 21.) Two or three thin beds of ore are present here, the lower being 15 to 18 inches thick; the upper ore about 10 inches thick. Accompanying the lower bed are a few inches of ore separated from it by about 2 feet of shale.

The following sections were measured in this locality:

Section of "Rockwood" ore lower seam, 3 miles south of Coal Creek.

(Pl. IV, 35, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore	..	4½
Shale	1	11
Ore, good quality, oolitic and fossiliferous with slickensided planes	1	3
Shale.		

Total ore, 1 foot 7½ inches.

The bed is overturned so that the dip is steep toward the southeast, and the strike is N. 30° E.

The ore shown here is of good grade, oolitic, and fossiliferous, and exhibits slickensided planes. These observations were made in a prospect at the side of a wagon road that crosses the mountain to Briceville. Stratigraphically above this bed, and separated from it by about 200 feet of shale, is a bed showing about 10 inches of ore that has been opened at the side of a small creek.

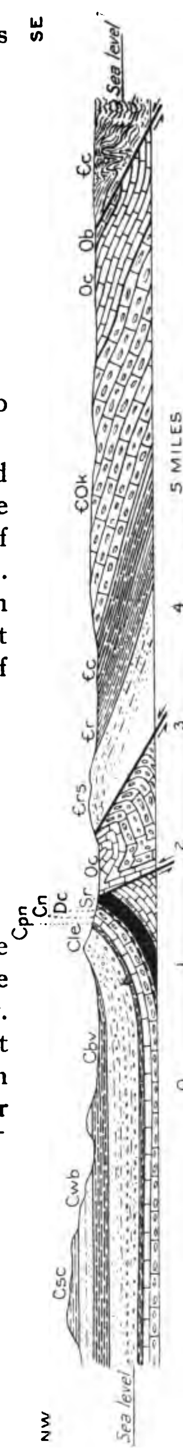
Section of "Rockwood" ore 2¾ miles south of Coal Creek.

(Pl. IV, 36, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, good quality, compact, slickensided.	1	6
Shale.		

Dip 29° S. 45° E. (overturned).

These observations were made on the west side of a small foothill at the base of Walden Ridge. The ore was hard and appeared to be of excellent quality. A sample block of ore was shipped from this prospect to the mineral exhibit at the Appalachian Exposition held in Knoxville September, 1911. About 40 car



€rs, Sandstone in Rome formation.
€r, Rome formation.
€c, Conasauga shale.
€Ok, Knox dolomite.
Oc, Chickamauga limestone.
Ob, Bays limestone.
Sr, "Rockwood" formation.
Dc, Chattanooga shale.
Cn, Newman limestone.
Cpn, Pennington shale.
Cle, Lee conglomerate.
Cbv, Briceville shale.
Cwb, Wartburg sandstone.
Osc, Scott shale.

FIGURE 20.—Northwest-southeast structure section from near Chamberlain to Walden Ridge. (From U. S. Geological Survey Folio No. 43.)

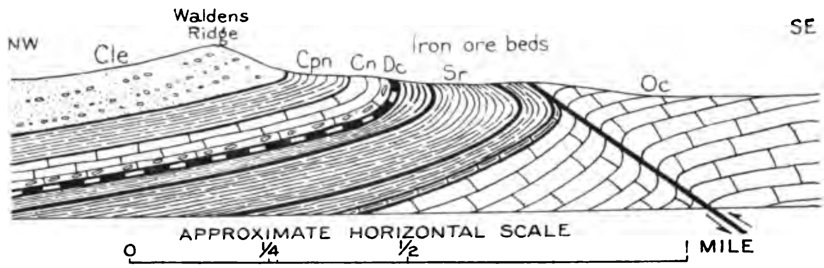


FIGURE 21.—Northwest-southeast structure section near Briceville. Shows overturned structure of "Rockwood" iron ore. (From U. S. Geological Survey Folio No. 33.)
Oc, Chickamauga limestone.
Sr, "Rockwood" formation.
Dc, Chattanooga shale.
Cn, Newman limestone.
Cpn, Pennington shale.
Cle, Lee conglomerate.

loads of ore were reported to have been mined from the outcrops near this place and shipped to furnaces at Rockwood many years ago.

Valley Areas.

In the portion of Tennessee included by the map, Pl. IV, there are several strips of "Rockwood" formation that lie in the Great Valley, as contrasted with the outcrop that is found in the ridges at the foot of the Cumberland escarpment. Some of these strips correspond in position with the Whiteoak Mountain syncline and are remnants of a fold that may have extended deeper into the crust of the earth than others in the valley and which consequently has not been entirely removed by erosion. The preservation in places of this syncline is due, in part, also to the fact that the "Rockwood" formation in the Great Valley areas contains a considerable thickness of resistant sandstone beds The principal valley areas are situated near Decatur, Rhea Springs, Euchee, Barnardsville, Chamberlain, and Clinton. The area between Chamberlain and Barnardsville is one of the most important in the State as a source of "Rockwood" ore, ranking second only to the Cumberland escarpment area near Cardiff The area near Euchee is also a factor in the ore production of Tennessee.

Northeast of Rhea Springs.—A narrow outcrop of the "Rockwood" formation lies 1 to 4 miles northeast of Rhea Springs in the upper part of the valley of Muddy Creek This strip of the formation is part of a much faulted area, and is bounded on the northwest by a fault which limits the ore in that direction to only a few hundred yards. There are apparently several thin seams of iron ore present here. The beds dip steeply toward the southeast, an indication of an overturn in the strata which normally should dip toward the northwest. The formation is composed here largely of shale and a section of the ore-bearing portions of the beds measures as follows:

Section of "Rockwood" iron ore seams and associated shale 2 miles northeast of Rhea Springs.

(Pl. IV, 38, and corresponding ore section.)

	Feet.	Inches.
Upper seam—		
Shale.		
Ore, soft	..	10
Shale	20	..
Second seam—		
Ore, soft	1	4
Shale	42	..
Third seam—		
Ore, soft	..	6
Shale	27	..
Fourth seam (total ore, 2 feet)—		
Ore, soft	..	6
Shale	..	2
Ore	1	6
Shale.		
Dip 45° E.		

The following section shows the thickness and character of one of the seams:

Section of "Rockwood" iron ore in wagon road 1¼ miles northeast of Rhea Springs.

(Pl. IV, 37.)

	Feet.	Inches.
Shale.		
Ore, soft, fractured and faulted	..	9 to 11
Shale.		
Dip very steep northwest (nearly vertical).		

Several carloads of soft ore are reported to have been mined from the outcrop northeast of Rhea Springs and shipped to furnaces at Rockwood many years ago.

Euchee (Crescent).—A strip of "Rockwood" formation near Euchee extends along Tennessee River for about 9 miles lying partly in Roane County and partly in Rhea County Much of this strip is in the bottom land of Tennessee River, and as the river in its widnings crosses the strip four times besides following the formation for some distance, much of the "Rockwood" area is below the river level. The structure of the northeast and southwest ends of this strip is synclinal, but on the southeast side the strip is bordered by a fault for about 5 miles. On the outcrop near the county line the rocks dip 20° to 30° southeast Soft ore has been mined in six or eight places along this strip on both sides of the river, and it is understood that nearlyall the available softore has been obtained. The Crescent mine of the Dayton Coal and Iron Company was visited in 1908. Hard ore was at that time mined here from an underground slope about 600 feet long. The ore is shipped by boat down Tennessee

River to a point opposite Dayton, and thence carried to the furnaces by railroad.

The ore beds as observed at the Crescent mine is 5 to 6 feet thick. From 10 inches to 1 foot of lean ore at the top is left for a roof. The ore that is worked is seamed with shale and calcareous material, so that the content of iron is rarely above 30 per cent in the hard ore, and the lime content is greater than is necessary for blast furnace practice.

Section of "Rockwood" iron ore near Euchee, Crescent iron ore mine, room 1 *near top of incline,* 1908.

(Pl. IV, 43, and corresponding ore section.)

	Feet.	Inches.
Ore, lean, left for roof	..	10
Ore, shaly	2	2
Ore, good	3	..
Shale.		
Total minable ore, 5 feet 2 inches.		

Section of "Rockwood" iron ore near Euchee, Crescent iron ore mine at breast of room No. 11, *5th level,* 800 *feet north of main slope.*

(Pl. IV, 43, and corresponding ore section.)

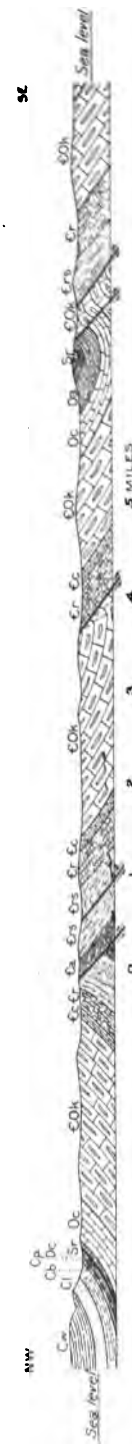
Shale.	Feet.	Inches.
Ore, lean, left for roof	..	10
Shale, separating smoothly from ore above	..	1 to 1½
Ore, calcareous	..	8 to 9
Shale	..	1 to 3
Ore, calcareous	..	6½
Shale	..	—½
Ore	..	9
Shale	..	1 to 2
Ore, bottom 2 inches very calcareous	..	6
Ore, fractured in places, mainly good but slightly argillaceous in fracture openings	2	0
Shale.		
Dip about 30° S. 50° E.		
Total minable ore, 4 feet 6½ inches.		

In the Crescent mine many small faults diagonal to the strike of the beds have been encountered. The faults are apparently all normal; that is, the rocks have slipped downward on the side toward which the fault plane inclines. The throw of the faults is very small, ranging from a few inches to about the thickness of the ore-bed or 6 feet. At right angles to the dip there are a few shallow rolls in the strata which render the ore horizontal in places or cause it to rise slightly for a short distance toward the southeast. There are also a few strike faults within the mine, and one of these has been overthrust so that the ore bed is duplicated in the section at one point in the mine. Where the two

portions of the ore bed that are overlapped are in contact the thickness of the minable ore is from 8 to 10 feet.

Chamberlain-Barnardsville.—Extending south-southwest from Tennessee River at a point about 3 miles above the mouth of Clinch River is a prominent ridge, the crest of which is formed by sandstone of the "Rockwood" formation. About 4½ miles from the river the ridge is cut in two by a branch of Riley Creek, which follows a low anticline, the axis of which is transverse to the major axis of folding. In the east slope of this ridge both northeast and southwest of Riley Creek is a fairly thick bed of "Rockwood" ore with a shale parting. The measures carrying ore are folded into an unsymmetrical syncline having dips of 15° to 30° on the northwest limb and very steep to vertical dips on the southeast limb, as indicated in the structure section, Fig. 22. The ore thus lies in two long canoe-shaped basins 4½ to 4¾ miles in length, and about one-fourth to one-third mile wide, and outcrops on the limbs and at the ends of the syncline. The photograph, Pl. XII, shows the syncline of ore, after the overburden had been removed, curving upward like the end of a spoon, at the northeast end of the syncline near Chamberlain.

The ore in the northeast basin consists of two benches, the upper 5 feet thick and the lower 2 feet thick, parted by 1 to 2 feet of shale. On the east limb of the syncline where the beds are nearly vertical, the ore is soft to a depth of 150 feet in places. On the west limb the ore is soft from the outcrop to a distance of 300 to 400 feet underground, where the cover is thin. The soft ore is very rich, carrying 45 to 50 per cent of iron. The hard ore is fossiliferous, high in lime, and lean in iron. The iron ranges from 25 to 36 per cent; the silica from 3.5 to 6 per cent; the alumina from 3 to 4 per cent, and the lime from 22 to 25 per cent.



Ca, Apison shale.
Crs, Sandstone in Rome formation.
Cr, Rome formation.
Cc, Conasauga shale.
COk, Knox dolomite.
Oc, Chickamauga limestone.
Oa, Athens shale.
Sr, "Rockwood" formation.
Dc, Chattanooga shale.
Cp, Fort Payne chert.
Cb, Bangor limestone.
Cl, Lookout sandstone.
Cw, Walden sandstone.

FIGURE 22.—Northwest-southeast structure section near Briceville shows overturned structure of "Rockwood" Iron Ore. (From U. S. Geological Survey Folio No. 4.)

In the southwest basin the ore lies in similar relations, having dips of 10° to 20° on the west limb, and being vertical or overturned on the east limb. The ore occurs in two benches, the upper of which is 3 feet thick, and the lower 2 feet thick. The shale parting is thicker here than in the area to the northeast, being about 6 feet thick. On the west limb the ore dips at nearly the same angle as the slope on the surface, so that it is under thin cover and there is a large area of soft ore that can be obtained by moderate stripping. The soft ore is of high grade, carrying in places above 55 per cent of iron. The ore in the lower bed is mostly hard and of lean to fair quality. Owing to its position below the 6-foot shale parting it can hardly be mined with the upper bench, and probably would not be considered minable alone under present conditions. The following eight sections were measured at the Chamberlain mines:

Section of "Rockwood" iron ore, Chamberlain mine, south basin, 1908, *"vertical" bed on the southeast line of syncline,* 1.4 *miles southeast of Barnardsville.*

(Pl. IV, 46, and corresponding ore section.)

	Feet.	Inches.
Ore	2	2
Shale	4	..
Ore	..	9
Shale	1	10
Ore	1	..
Shale	..	2
Ore	1	4
Shale.		

Dip 60° toward southeast.

Total ore, 5 feet 3 inches.

Section "Rockwood" iron ore, top bench on west limb of syncline, 1.1 *miles southeast of Barnardsville.*

(Pl. IV, 47, and corresponding ore section.)

	Feet.
Shale.	
Ore	3
Shale.	

Dip 7° S. 60° E.

Section of "Rockwood" iron ore "vertical" bed about 1.6 *miles southeast of Chamberlain mine.*

(Pl. IV, 49, and corresponding ore section.)

	Feet.	Inches.	
Shale.			
Ore	2	6	Upper bench.
Shale, with ferruginous streaks	2	9	
Ore	2	10	
Shale, with ferruginous strip in middle	1	6	
Ore (lower bench)	3	..	
Shale.			

Dip nearly vertical, slightly overturned to northwest.

Total ore, 8 feet 4 inches.

Section of "Rockwood" iron ore on "vertical" bed about 1.6 *miles southeast of Chamberlain mine.*

(Pl. IV, 49, and corresponding ore section.)

	Feet.	Inches.	
Shale.			
Ore, upper bench	5	..	
Shale	..	4 to 6	
Ore running laterally into shale	2	..	
Shale	..	7	
Ore	4	..	Lower bench.
Shale	..	3	
Ore	..	8	
Shale.			

Dip nearly vertical: slightly overturned to northwest.

Total ore, 11 feet 8 inches.

Section of "Rockwood" iron ore in open cut at Chamberlain mine, 1903.

(Pl. IV, 50, and corresponding ore section.)

	Feet.	Inches.	
Shale.			
Ore	4	6	Upper bench.
Shale	..	2	
Ore	..	7	
Shale	1	9	
Ore	..	7	Lower bench.
Shale	..	3	
Ore	1	10	

Dip 15° toward southeast.

Total ore, 7 feet 6 inches.

Section of "Rockwood" iron ore, lower bench at open cut, Chamberlain mine.

(Pl. IV, 50, and corresponding ore section.)

	Feet.	Inches.
Shale (parting between lower and upper bench)	..	6 to 10
Ore	..	2 to 6
Shale	..	2 to 4
Ore, hard	1	8
Shale.		

Dip 19° S. 50° E.

Total ore, 1 foot 10 inches, to 2 feet 2 inches.

Section of "Rockwood" iron ore on "upright bed" in entry at Chamberlain mine, 40 *feet below outcrop.*

(Pl. IV, 51, and corresponding ore section.)

	Feet.	Inches.	
Shale.			
Ore, soft, good quality	2	9	Upper bench.
Shale	..	2 to 5	
Ore, soft, good quality	..	5	
Shale	1	9	
Ore, soft, fair quality	..	8	Lower bench.
Shale	..	2½	
Ore, soft, fair quality	1	6½	
Shale.			

Dip about 80° toward northwest.

Total ore, 5 feet 4½ inches.

Section of "Rockwood" iron ore, upper bench at northeast end of syncline, shown by open cut 1¼ miles north of Chamberlain postoffice.

(Pl. IV, 52.)

	Feet.	Inches.
Shale.		
Ore, parted by 2 or 3 seams of shale aggregating about 10 inches thick	4	10
Shale.		

Dip varies. Low dip to southwest along axis of syncline and vertical, or overturned to southeast on southeast limb of syncline.
Total ore, 4 feet.

Mining operations have been carried on in the northeast basin from the end near Tennessee River southwestward about 3½ miles. A great deal of mining by stripping has been done here through a period of more than 25 years, and this form of mining is still in progress in a small way. Shale was stripped to a maximum thickness of 30 feet near Hackler Gap (see Pl. XII), although much of the ore thus uncovered was hard and rather lean. Ore is mined underground from the vertical or "upright" bed on the east limb of the syncline, adits being driven on the strike of the bed from both ends of a hill until they meet. The ore is stoped overhand and milled down through airways into the bins above the adits and is then trammed by mules to the tipples over the railroad cars. At the extreme northeast end of the basin, near Tennessee River, where the syncline curves up to the surface in the shape of a spoon the overlying shale has been removed from the ore beds. In October, 1908, the uncovered ore bed was visible for 300 yards along the strike at the northeast end of the basin, showing most perfectly the nonsymmetrical synclinal structure that is characteristic of the whole deposit. (See Pl. 11.)

The ore in this locality is owned and mined by the Roane Iron Company. The product is carried on the company's railroad from Chamberlain to Tennessee River, where the cars of ore are transferred to a barge and towed by a stern-wheel steam boat down the river to a point near the mouth of Caney Creek. Here they are picked up by a locomotive and hauled over a branch of the Cincinnati, New Orleans and Texas Pacific Railway to Cardiff. From Cardiff the ore is carried over the main line of the same railway to the furnaces at Rockwood. The company's railroad is now being extended southwest to reach the ore basin southeast of Barnardsville, which will soon be developed.

Clinch River.—In the valley of Clinch River both northeast and southwest of Clinton, the "Rockwood" formation outcrops in several disconnected strips having the same general strike. One of these strips lies about 1 mile southeast of Clinton, and outcrops in a range of hills formed by a resistant sandstone in the formation. This range of hills extends, with several breaks or gaps, for a distance of about 8 miles toward the southwest, and is known as Lost Mountain. Another area

PLATE XII

Open Cut Showing Upper End of Synclinal Basin of "Rockwood" Iron Ore, 2 Miles Northeast of Chamberlain, Tennessee.
Overlying Shale has been Stripped from Ore Bed.

Photo by E. F. Burchard.

lies from 1½ to 3½ miles northeast of Clinton, and a few miles farther northeast a third area begins. This latter area is described in the portion of the text entitled "Northeast Tennessee." These valley areas of "Rockwood" formation contain more sandstone than do those which outcrop at the base of Cumberland escarpment. Previous geologic studies by Keith [1] in northeast Tennessee have indicated that, in this area at least, the iron ore seams are best developed where the "Rockwood" formation consists very largely of shale, and in the geologic maps of the Briceville and Maynardville folios no ore-bearing formations are shown in the Clinch Valley. In view of the fact that many reports have reached the State Geological Survey with regard to the occurrence of ore in the Clinch Valley, it was decided to investigate the matter, and Prof. Charles H. Gordon kindly visited the area and obtained the following section:

Section of "Rockwood" formation on Southern Railway 1 mile south of Clinton.

(Pl. IV, 54.)

	Feet.
Shale, sandy	200 to 300
Iron ore (reported)	1½
Sandstone, hard, ferruginous, irregularly bedded	50
Shale and sandstone	40
Sandstone, white and brown	20
Shale, sandy	200

The "Rockwood" formation thus appears to be 500 to 600 feet thick in this locality, and to contain at least one bed of iron ore in places. The dip of the rocks is about 40° S. 60° E. On the east the "Rockwood" formation is cut off by a fault which brings lower limestones and shales into juxtaposition with it. The gaps between the strips of "Rockwood" ore are due to the changes in direction of this fault, which in places has cut across the strike of the formation.

The presence of iron ore was observed at only one locality, viz., in a gap in the ridge about one-half mile southwest of the railway, or about 1½ miles south of Clinton (Pl. IV, locality 53). From an opening made about 30 years ago some ore was obtained, pieces of which still lie scattered about. The excavation had become filled up, and the thickness of the ore bed could not be measured. The ore bed is reported by residents of the locality as being continuous for several miles.

Decatur.—One-half mile east of Decatur, Meigs County, lies a narrow area of "Rockwood" formation in which a few thin seams of iron ore occur. The ore-bearing formation extends from Goodfield Creek northeastward for a distance of about 3 miles, along the southeast slope of a

[1]Keith, Arthur, Description of the Briceville and Maynardville quadrangles, Folios Nos. 33 and 75; Geol. Atlas U. S., U. S. Geol. Survey, 1896 and 1901.

low ridge. This strip of "Rockwood" formation lies in the direction of the strike of the Whiteoak Mountain syncline, and is evidently on the same structural axis. On the southeast the "Rockwood" beds are cut off by a fault so that their extent laterally, or on the dip, is probably not more than 300 to 400 yards. This locality was visited in November, 1911, and it was found that the ore outcrops in three or four seams on the southeast slope of the ridge, the crest of which is formed by sandstone in the lower half of the "Rockwood" formation. The dip toward the southeast of the seam that outcrops highest on the slope is from 30° to 55°, and those at the base of the hill and in the valley dip about 15°. The ore seams are all contained within about 400 feet of the formation. The upper part of the formation is composed of shale and sandstone; the seam nearest the top of the ridge,—the lowest one stratigraphically—is apparently of the best quality, but blocks of soft ore embedded in debris from pits and old trenches made on the outcrop indicate that the seam is not over 6 inches in thickness.

This seam was mined by stripping for a distance of several hundred yards south of Dry Fork of Suee Creek not long after the Civil War, and the ore was hauled by wagons to a near-by forge where iron was made for local use. A prospect pit was made here at the time of visit, to a depth of about 5 feet, but failed to get through the residual clay, back-filling, and debris, consequently the ore could not be measured. About 75 feet lower, vertically, on the hill slope, the presence of a seam of ore possibly 10 inches thick is shown by much debris. Pits were also dug in search of this seam, and in the residual material covering the hill slope chunks of ore were found 5 inches thick. Most of this ore is rather dark and siliceous, but there are streaks of rich iron oxide in it. About 65 feet still lower vertically, not far above the bottom of the hill, a third seam of ore was found in place near a spring. This ore was badly shattered and slightly offset by a fault, as shown in the prospect pit, but the most accurate measurements that could be made under the circumstances showed a seam about 18 inches thick, dipping 55° or more S. 60° E. The details of this section are as follows:

Section of "Rockwood" iron ore 2½ miles northeast of Decatur.

	Feet.	Inches.
Shale.		
Ore, dark and siliceous, with crust of limonite at top and thin streaks of shale within	1	6
Shale.		
Dip 55° S. 60° E.		

This ore is only of fair quality, much of it being dark and siliceous. Some limonite in scales and rectangular matrices occurs on the top of this seam and on the seam next above. This limonite ore seems to be a

replacement of the shale on top of the ore. Stringers of it occur also between the laminae of the shale, and as a filling between joints in the shale adjacent to the ore.

About one-third mile northeast of the section near the spring, a bed of ore, which is probably the one outcropping near the spring, appears in the bed of Dry Fork of Suee Creek. The ore here is hard, since it is below the water part of the year. This bed is 15 to 18 inches thick, and dips about 15° S. 65° E.

Another seam outcrops in a wagon road about 150 yards northeast of the outcrop in Dry Fork, but the seam is only 3 to 4 inches thick. This apparently makes four distinct seams. On the east slope of this ridge for three-fourths mile test pits have been sunk very close together and ore has evidently been found in many of them, but in some there seems to have been no ore. The hill slope is thickly covered with residual clay, soil, and debris. Roots extend down three to four feet and prospecting is difficult.

Resume.—Sections and Analyses.

According to the data with regard to the ore beds in central East Tennessee, and referring to the map Pl. IV, it will be noted that there are some very important areas of red iron ore here. At present this is the most productive portion of the State. Along Cumberland escarpment between Sheffield and Glen Alice, there are generally two thin seams of ore the thicker of which measured less than 2¼ feet, but in the vicinity of Glen Alice its thickness increases, and thence northeastward past Rockwood and Cardiff to Emory Gap the bed is normally from 2½ to 4 feet thick and in places reaches a maximum of 8 feet. The ore here is of comparatively high grade, the hard ore commonly carrying 35 to 42 per cent of metallic iron, 6 to 12 per cent silica, 4 to 8 per cent alumina, 10 to 15 per cent lime, 1.5 to 4 per cent magnesia, 0.5 to 0.6 per cent phosphorus, and from a trace to 1 per cent of sulphur. The largest underground iron mines in the State are in the Rockwood-Cardiff area. Near Emory Gap the continuity of the bed is broken by a fault, but near Harriman a measurement showed 2 feet 4 inches of soft ore. From near Harriman northeastward to Coal Creek the outcrops of "Rockwood" ore are broken by several faults and the thickness of the bed is from a few inches to about 2 feet.

Certain of the Valley areas of central East Tennessee contain important reserves of "Rockwood" iron ore. In the Euchee area the bed is more than 5 feet thick, but the ore is lean. In the Chamberlain-Barnardsville area are two synclinal basins of ore that will furnish a supply to the Roane furnaces for many years. Five to eight feet of a fair grade of hard ore occur here, and there is still available considerable rich soft ore.

The accompanying graphic sections and chemical analyses will afford a fairly definite idea of the character of the ore beds in Central East Tennessee:

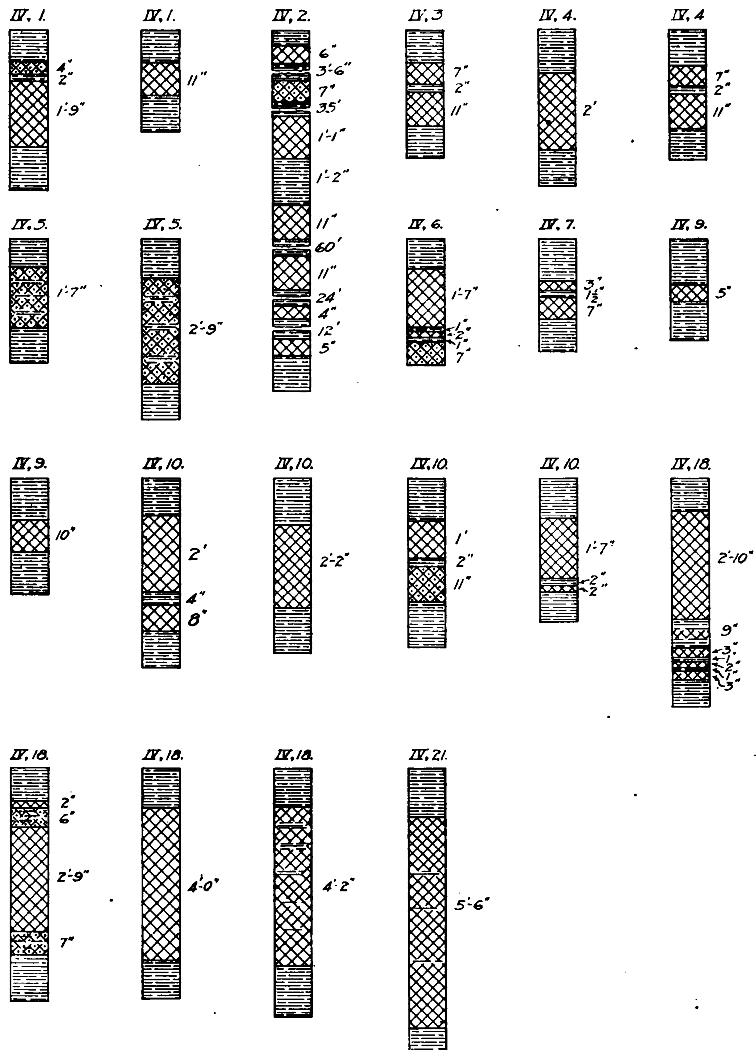


FIGURE 23.—Graphic sections of "Rockwood" iron ore beds, Central East Tennessee.

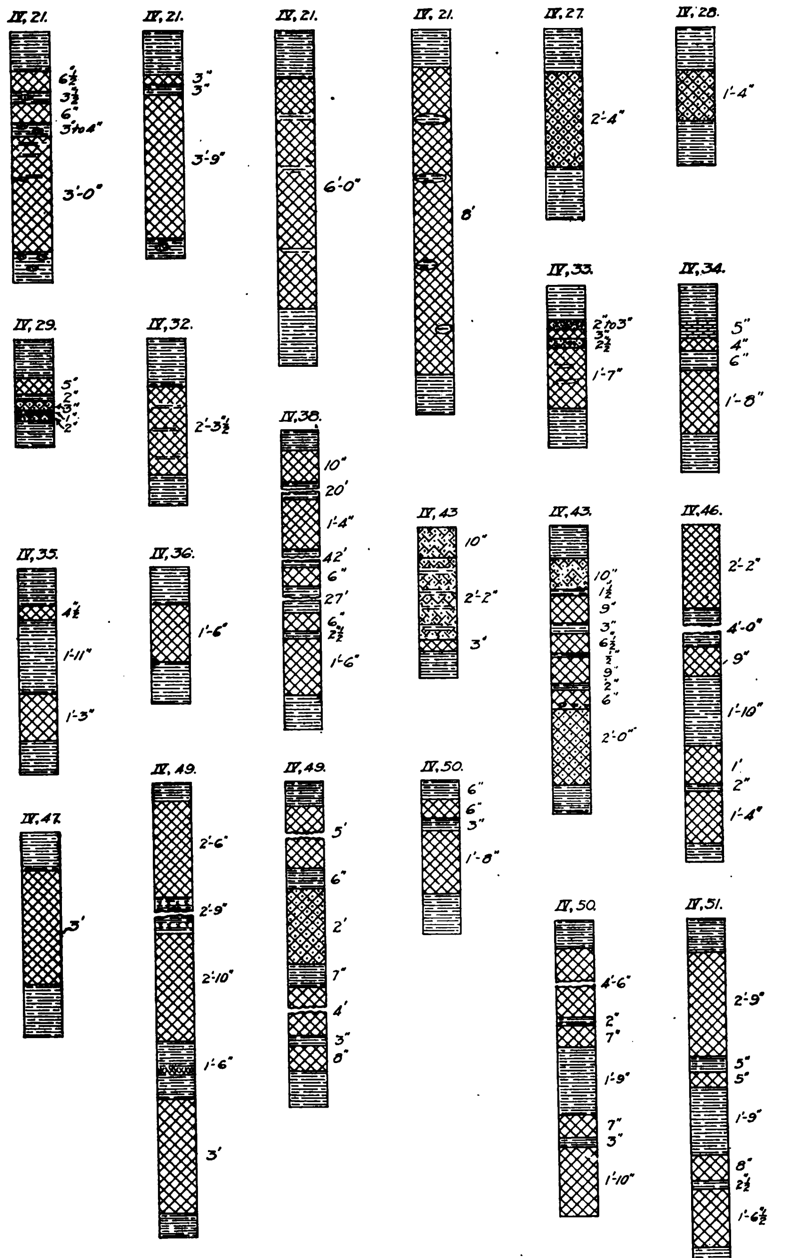


FIGURE 24.—Graphic sections of "Rockwood" iron ore beds, Central East Tennessee (continued).

Analyses of "Rockwood" iron ore, central East Tennessee.

Locality.	Authority.[1]	Fe	SiO_2	Al_2O_3	CaO	MgO	Mn	P	S	H_2O
Rockwood-Cardiff:										
Baker slope—										
Hard ore..............	R	38.75	8.60	4.92	13.86	2.29	......	......	1.93	......
Do	R	39.00	13.90[2]		9.10	......	......	......	......	......
Do	R	37.34	6.78	3.90	14.00	3.63	......	......	1.025	......
Do	R	36.76	6.30	5.65	13.64	3.83	......	......	......	......
Do	R	39.14	5.99	4.90	12.69	2.49	......	......	.129	......
Do	R	39.25	6.46	4.28	11.60	3.16	......	......	.08	......
Do	R	35.19	7.81	5.38	13.69	3.19	......	......	.220	......
Do	R	39.25	6.46	4.28	11.60	3.16	......	......	.096	......
Do	R	39.55	7.29	4.86	11.14	2.96	......	......	.055	......
Warner slope—										
Hard ore..............	R	38.00	7.51	5.95	10.85	4.23	......	......	.124	......
Do	R	38.00	4.61	5.85	10.85	4.23	......	......	.12	......
Dyke slope—										
Hard ore..............	R	37.00	8.92	8.11	9.76	3.42	......	......	.226	......
Do	R	38.08	10.60	......	10.13	......	.18	.56	.16	......
Do	R	37.50	11.14	8.01	9.75	3.50	......	......	......	......
Do	R	37.00	8.72	8.11	7.96	3.42	......	......	.123	......
Do	R	42.63	3.85	6.74	8.74	2.70	......	......	.160	......
Soft ore surface.........	R	50.19	12.58	9.82	1.15	......	.92	......	trace	......
Cardiff slope—										
Hard ore..............	R	41.80	6.75	7.00	9.60	2.48	......	......	.165	......
		46.40	6.35	4.45	10.48	2.33	......	......	......	......
Do	R	35.60	10.46	5.70	10.90	......	.15	.59	.08	......
		41.80	6.75	7.00	9.60	2.48	......	......	.16	......
Do	R	38.27	7.45	5.73	12.03	3.98	......	......	.179	......
Do	R	40.46	7.88	5.65	10.30	2.31	......	......	trace	......
Do	R	42.90	6.00	5.56	9.39	2.66	......	......	trace	......
Wright slope—										
Hard ore..............	R	26.10	6.11	6.51	20.43	......	......	......	......	......
	R	34.53	5.70	6.64	15.01	......	......	......	1.510	......
Do	R	35.10	8.08	5.27	14.00	2.59	.15	.60	0.84	......
	R	37.40	5.78	5.34	14.35	......	......	......	0.841	......
Do	R	34.68	7.14	5.67	16.33	......	......	......	......	......
	R	36.31	5.00	5.84	14.52	......	......	......	0.499	......
	R	32.74	8.17	7.65	14.30	......	......	......	0.900	......
		35.30	4.60	4.45	16.86	2.00	......	......	0.72	......
	R	32.03	6.92	7.43	15.84	1.80	......	......	1.25	......
Carters slope—										
Hard ore..............	R	37.80	6.20	3.35	12.56	......	......	......	......	......
Howard slope—										
Hard ore..............	R	36.85	11.60	10.05	9.30	3.35	......	......	......	......
Do	R	33.35	15.35	8.60	6.88	......	.15	.60	.15	3.92
Do	R	37.13	8.56	5.25	11.55	4.37	.32	......	.206	......
	R	39.96	8.10	5.46	10.00	3.98	......	......	.083	......
Do	R	41.30	9.55	5.60	9.24	......	......	......	.127	......
Do	R	39.10	9.57	7.10	9.05	2.44	......	......	.510	......
Suddath slope—										
Hard ore..............	R	34.65	6.85	4.01	17.11	2.80	......	......	.168	......
Do	R	34.65	6.85	4.01	17.11	2.80	.36	......	.07	......
Do	R	36.13	5.81	3.83	16.66	2.57	......	......	.083	......
Do	R	35.52	6.05	3.99	15.58	1.50	......	......	.013	......
Do	R	38.37	6.45	3.64	14.73	2.32	......	......	......	......
Do	R	23.55	8.88	5.32	24.63	1.83	......	......	......	......
Patton slope—										
Hard ore..............	R	41.82	8.05	5.30	9.47	3.39	......	......	.020	......
Do	R	40.55	7.88	6.03	9.90	3.49	.18	.59	.08	......
Do	R	40.46	7.03	6.11	9.92	3.34	......	......	.022	......
Do	R	38.16	8.45	6.45	10.90	4.07	......	......	.030	......
Durrell slope—										
Soft ore..............	R	47.27	13.10	6.70	......	......	......	......	......	......
Do	R	48.30	9.75	6.20	......	......	......	......	......	......
Rockwood-Cardiff district:										
Natural basis:										
Average, 6 mines, Mar. & Aug., 1909..........	R	37.32	10.20	5.76	11.16	2.57	.13	.56	.12	2.22
Slate not picked out.										
Average, same mines, June 1910. Slate picked out................	R	39.35	9.04	5.78	10.55	2.31	.16	.58	.12	2.61

[1]Authorities: R, Roane Iron Co.
[2]Insoluble.

Analyses of "Rockwood" iron ore, from valley outcrops, central East Tennessee.

Locality.	Authority.[1]	Fe	SiO_2	Al_2O_3	CaO	MgO	Mn	P	S	H_2O
Ironton:										
Hard ore	C	26.97	7.52	4.50	23.92	1.73	0.35		.042	
Do	C	31.00	4.40	3.43	24.13	0.72				
Do	C	24.25	10.65	6.63	22.50	1.65				
Do	C	30.14	4.30	3.50	23.58					
Do	C	28.05	3.50	2.65	27.08	0.81	0.32		trace	
Do	C	25.66	5.90	4.60	26.66	1.71				
Euchee:										
Hard ore—										
Crescent slope	D	26.50	9.10	6.28	22.25	1.43		.416		
Do	D	29.80	5.42	5.06	21.78	1.60				
Do	D	32.00	7.69	5.58	18.45	1.48		.446		
Soft ore—										
River Mines	D	45.80	11.72	7.10						
Do	D	47.40	14.76	8.70						
Round Island:										
Hard ore	R	29.50	6.80	14.65	19.99	0.91				
Soft ore	R	49.39	16.50	10.10						
Do	R	50.30	7.95	6.43						
Do	R	41.90	16.83	21.43						
Chamberlain:										
Hard ore	R	25.20	3.48	3.25	25.15	1.84				
Do	R	36.90	6.10	3.01	14.10	1.83	.12	.38	.07	
Do	R	29.06	7.00	3.79	22.97	1.20			.07	
Do	US	37.32	7.92	3.07	13.77	1.71	.33	.572	.05	6.11
Do	US	27.22	5.00	2.82	24.84	1.63	.30	.432	.05	5.61
Do	R	32.36	5.84	18.09					.062	
Do	R	29.06	5.34	22.97					.069	
Do	R	28.60	11.36[2]		19.10			.476		
Soft ore	R	50.25	10.90	5.75						
Do	R	45.91	12.22[2]							
Do	US	52.55	7.62	4.31	.40	.47	.31	.533	.02	10.01
Do	US	50.79	7.63	3.64	1.68	.50	.58	.737	.07	8.99
Do	R	51.40	10.00	5.37						
Dry basis		48.	16.38							
Do	R			6.23	.20					
Natural		43.61	14.88							
Red Cloud:										
Hard ore	R	37.26	6.94	6.05	16.25	1.04				
Soft ore	R	48.86	8.44	9.43	4.83	.97				
Deathridge:										
Soft ore	R	57.97								
Do	R	50.43								
Do	R	53.76								

[1]Authorities: C, Citico Blast Furnace Co.; R, Roane Iron Co.; D, Dayton Coal and Iron Co.; US, United States Geological Survey.

[2]Insoluble.

NORTHEAST TENNESSEE.

The "Rockwood" iron ore outcrops in one continuous strip at the foot of the Cumberland escarpment in northeast Tennessee at the border of Powell Valley from Caryville northeast to Cumberland Gap, a distance of about 27 miles. The iron mines at La Follette and near Arthur are in this strip. These relations are shown on the map Pl. V. The "Rockwood" ore outcrops also in the valley of Elk Creek for a distance of about 5 miles southwest from the town of Elk Valley, and probably extends from one valley to the other in a basin below Cumberland mountain.

Elk Valley Area.

The "Rockwood" formation in the Valley of Elk Creek is faulted and badly broken. It outcrops n three strips, running from about 200 to 2,200 feet in width; separated in places by strips of Chattanooga shale and Newman lime tone. To the northwest the Carboniferous Briceville sha e is faulted against and und r the "Rockwood," and two faults running northeast-southwest cause the repetition of "Rockwood" strata toward the southea t. Finally toward the southeast the rocks pass in normal sequence below the Carboniferous Lee conglomerate in Pine Mountain.

The ore beds that have been opened by prospecting lie mainly in the strip of the "Rockwood" formation on the northwest side of the valley adjacent to the coal fields and about three-fourths to seven-tenths mile from the Southern Railroad. Mining has been attempted here only in a small way, and a few cars of ore were shipped to the blast furnace at Middlesboro, Ky., but no work has been done for many years. There are two easily identified seams of ore, and probably a third, in this locality, although only one appears to be of important thickness. Several measurements were made of these ore seams in September, 1911, and the observed thickness ranged from 12 to 48 inches. The more important details of these measurements are as follows:

Section of ore seam three-fourths mile southwest of Elk Valley.

(Pl. V, 1, and corresponding ore section.)

	Feet.
Shale.	
Ore, semi-hard to soft, fine-grained, slightly fossiliferous, slickensided, and much jointed. Shows argillaceous partings of knife-edge thickness	1
Bottom concealed.	
Dip steep toward northwest.	

The measurement was made in an old, nearly obliterated prospect and the ore appears to be the upper of two seams that are indicated by prospects about 200 feet apart across the formation. Much ore debris was plowed up in the surrounding fields. The ore breaks easily into angular fragments and appears to be of fairly good quality.

Section of ore seam 2 miles southwest of Elk Valley.

(Pl. V, 2, and corresponding ore section.)

	Inches.
Shale.	
Ore, fine-grained, compact, jointed and slickensided, leached and altered to limonite in some places	4
Shale	4
Ore similar to above	4
Shale.	
Dip 55° N. 40° W.	
Total ore, 8 inches.	

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This section was measured in a roadside ditch. The ore is fine-grained, finely fossiliferous, compact, jointed, and slickensided. The lime has been leached out and the ore shows alterations to limonite in places. The dip is 55° N. 40° W.

Section 3.3 *miles southwest of Elk Valley.*

(Pl. V, 3, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, disintegrated, sandy, with few knife-edge shale partings.	2	4
Shale.		
Dip nearly vertical.		

This section was also measured in a roadside exposure but the ore was not very well exposed on account of its disintegrated condition and it was impossible to determine whether there were fully 28 inches of ore or whether it included some shale partings. The ore was rather gritty and sandy, and was much jointed and slickensided. The dip was nearly vertical and the strike was N. 80° E.

A little less than one-half mile farther south a bed that lies lower stratigraphically outcrops for about 50 yards along the road. The dip is nearly perpendicular, the strike N. 65° E. The ore-bearing material measures 45 inches or more across, but is so weathered that not more than 23 inches can be positively identified as ore. The rest may be ferruginous shale.

Section 4 *miles southwest of Elk Valley.*

(Pl. V, 4, and corresponding ore section.)

	Feet.	Inches.	Feet.	Inches.
Shale.				
Ore, soft, compact, dark, slickensided and jointed, generally of good quality.......	3	9 to	4	..
Shale.				
Dip steep to northwest.				

This exposure was measured in the middle of the road, and the bed extends in the direction of the road for 100 yards or so. The dip is very steep to the northwest. The ore is dark, compact, slickensided, and jointed, and is apparently of fair quality. The bed appears to lie about 500 feet east of the bed at v, 3, and midway between the two is a seam about 1 foot thick.

Section 4¾ *miles southwest of Elk Valley.*

(Pl. V, 5, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, soft, dense, fine-grained, dark red, slickensided, jointed, contains crinoid stems and broken shells.............	4	0
Shale.		
Dip 45° to 60° S. 70° E.		

This measurement was made in a large, partly filled pit reported to have been 14 feet deep, from which it was planned to ship ore by means of an incline to the railroad one-fourth mile southeast. The ore showed in the form of a broken ledge, measuring in all 48 inches thick but having eroded crevices that were filled with dirt, possibly representing the position of shaly streaks. It was reported locally that there were 3½ feet of ore and some shale partings. The ore fragments on the dump represented a high grade soft ore, dense, fine-grained, slickensided, and jointed dark red ore of granular texture and containing crinoid stems and finely broken shells.

From the brief observations made near Elk Valley it would appear that the ore bed is thicker toward the southwest than it is near the northeastern area near the town. Farther toward the northeast the beds have been so badly overturned by the disturbance accompanying the faulting that they are not in a very favorable position for underground mining. The normal dip is toward the southeast, but even where the beds dip normally here there can not be a large extent of ore extending down the dip on account of an intermediate fault which cuts off the ore against the lower beds of the "Rockwood" formation. (See map Geologic Folio No. 33, U. S. Geological Survey.)

The ore southwest of the town of Elk Valley that might be mined from the outcrop probably does not exceed an average of 3½ feet in thickness, nor extend more than 3 miles from northeast to southwest. There are two other strips of "Rockwood" formation exposed in Elk Valley, southeast of and parallel to the strip in which the ore outcrops. No ore outcrops in these latter strips on account of faults which have buried the outcrop. Along the Southern Railroad near Stanfield the ore should be reached by drilling at depths less than 400 feet, and from this strip of the formation the ore should be found to extend under Pine Mountain and the Cumberland Plateau, possibly all the way to the outcrop on the northwest side of Powell Valley.

Powell Valley.

The strip of "Rockwood" formation that outcrops in the foothills of Cumberland Mountain on the west side of Powell Valley is mostly steeply inclined and is consequently very narrow. Normally the dips are toward the northwest but in many places the ore beds have been noted as dipping steeply southeast. This is due to an overturn of the upper portions of beds which will be found to resume their northwest dip if followed deep enough below the surface, and this dip will greatly lessen until the rocks become nearly flat below the plateau west of Cumberland Mountain. (See Fig. 25.) As stated on page 81 the ore-bearing formation extends in this locality from Carey-

ville on the southwest, northeast for 27 miles or more, to Cumberland Gap, where it is cut off by a fault near the Tennessee-Virginia line. At Careyville the outcrop is cut by a fault which brings the Briceville shale into contact with the "Rockwood" formation.

The ore was examined in the vicinity of Careyville, La Follette, and near Cumberland Gap in the course of the survey.

Careyville.—About 1 mile north of Careyville the ore bed was measured and found to be 33 to 34 inches thick, including a 1-inch shale parting. The ore at this point is not in its normal position, the folding of the region that resulted in the extensive fault about one-half mile southwest having changed the strike of the beds to the northwest and folded the ore locality into a narrow anticline. The old prospect visited showed the following section made in one vertical limb of this close fold:

Section 1 mile north of Careyville.

(Pl. V, 6, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, very soft, rich red color, heavy, granular, and fossiliferous, much fractured and slickensided	1	5
Shale	..	1
Ore, slightly argillaceous and sandy, with a knife-edge parting of shale locally near base	1	6
Shale.		
Dip 85° toward southwest.		
Total ore, 2 feet 11 inches.		

This ore was measured at the mouth of an old prospect drift. The ore is very soft physically. The top 17 inches is shown at the right of the face. It is red in color, and heavy, granular, and fossiliferous. It is much fractured and slickensided. The lower 18 inches contains some argillaceous and sandy material and is so decomposed that it is difficult to tell just how much shale it contains.

It is reported that several car loads of soft ore were mined many years ago from this old caved-in drift, hauled by wagon to the railroad, and shipped to a blast furnace in southern Kentucky.

La Follette.—At La Follette the "Rockwood" ore occurs in one important bed in which there are 3 feet 10 inches to 5 feet of ore, separated by several shale partings. The ore stands nearly vertical here or else dips steeply toward Cumberland Mountain. This structure is discussed in more detail on page 142. The following sections were measured at La Follete.

Section of "Rockwood" iron ore in Seneca mine entry, 2 miles southwest of LaFollette.

(Pl. V, 7, and corresponding ore section.)

	Feet.	Inches.
Shale.		
Ore, hard	1	..
Shale	..	2½
Ore, hard	..	6
Shale	..	3
Ore, hard, with a few thin steaks of shale	2	8½
Sandstone ("jackrock") ferruginous in places	..	6
Shale.		

Dip 26° to 30° toward northwest, becoming steeper near outcrop where it is overturned.

Total ore, 4 feet 2½ inches.

This section was measured at the face of a drift at the bottom of a hollow on the same level with the ore tunnel. The ore in the section is hard and the dip toward the surface becomes steeper and is overturned so as to dip southeast. The ore is worked by stoping overhead up the bed and chuting down to the drift where it is loaded into cars. The rooms are driven through to the surface 6 or 7 feet to over 20 feet wide, and the height equals the thickness of the bed. The pillars run 13 to 14 feet wide and are drawn after room driving has proceeded four to six pillar widths. The output in October, 1911, was about 60 tons a day from this opening. The ore produced constitutes about one-fourth the charge used at the furnace. It is hauled in tram-cars to a tipple on the L. & N. R. R., about 1½ miles from this opening, then from the tipple to the furnace it is carried about 2 miles in standard gauge cars.

Ore was formerly mined near the gap through which Big Creek flows at La Follette, and is reported to have been worked to a depth of nearly 200 feet without any change in dip, which was nearly vertical.

The following partial section of the ore bed was made at the only exposure near Big Creek Gap:

Partial section of "Rockwood" iron ore at mouth of old No. 2 shaft, LaFollette.

(Pl. V, 9.)

	Feet.
Shale.	
Ore, soft, oolitic in streaks, contains a 2-inch shale parting, and is much fractured and slickensided. Not well exposed, but thickness about	3
Shale.	

Dip 75° toward northwest.

About 1 mile northeast of Big Creek Gap the following section was measured at the mouth of one of the old entries:

Section of "Rockwood" iron ore at old entry No. 16, LaFollette.

(Pl. V, 11, and corresponding ore section.)

Shale.	Feet.	Inches.
Ore, soft	1	..
Shale	..	7
Ore, soft	1	4
Shale	2	2
Ore, soft, including 2 shale partings, 2 inches and 4 inches thick, respectively	3	3
Shale.		
Dip 70° toward northwest.		
Total ore, 5 feet 1 inch.		

According to this section there are 5 feet 1 inch of ore in a section of 8 feet 4 inches thick. It was reported that the ore bed in this entry was generally about 3 feet 10 inches thick, including a thin parting of shale near the bottom.

One-fourth mile northeast of old entry No. 16 the following section was measured:

Section of "Rockwood" iron ore 1¼ miles northeast of LaFollette, near mouth of slope No. 3.

(Pl. V, 12, and corresponding ore section.)

Shale.	Inches.
Ore, soft	1½
Shale	4 to 6
Ore, soft	9
Shale	4
Ore, soft	10
Shale	3½
Ore, soft brown color	4
Shale	2½
Ore, soft	7
Shale	1½
Ore, soft	6
Shale.	
Dip 82° toward NW.	
Total ore, 3 feet 1½ inches.	

This is a section of badly weathered ore outcropping in a small hollow at a point about 25 feet northwest of the mouth of the new slope No. 3 that was being started in October, 1911. On account of the weathered condition the shale showed considerable spread in the partings and it is reported that the proportion of shale is much less where the unweathered ore is opened at a lower level. The new slope that had just been started at the time of visit is inclined at an angle af about 26½° and extends

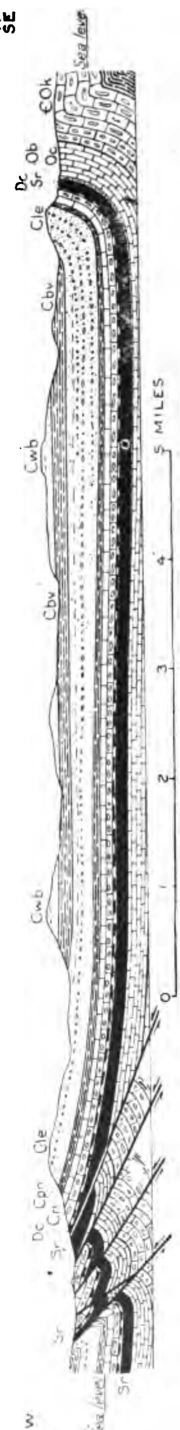

FIGURE 25.—Northwest-southeast structure section from LaFollette to Elk Valley. Shows probable position of "Rockwood" iron ore-bearing formation beneath Cumberland plateau. (From U. S. Geological Survey Folio No. 33.)

parallel with the strike of the ore. It was planned to drive levels back to the ore at vertical depths of 100 to 200 feet and to work the ore by stoping overhead. The ore is to be transported from this slope by a narrow-gauge tramway 7,200 feet long, motor power being a dinky locomotive. Connections will be made at La Follette with the standard gauge ore cars, which will carry the ore to the furnace.

The hard ore at La Follette ranges generally in metallic iron from 24 to 33 per cent; in silica, from 4½ to 17 per cent; in alumina, from 2.5 to 7 per cent; in lime oxide, from 13 to 16 per cent; in magnesium oxide, from 4.5 per cent to 7 per cent; in phosphorus, from .3 to .7 per cent; and in manganese from .25 to .5 per cent. The soft ore carries from 37.5 to 45 per cent metallic iron, with the other ingredients reduced proportionally. The hard ore as mined at present carries an average of about 25.5 per cent metallic iron, and the soft ore about 37.3 per cent metallic iron. (See analyses page 150.)

Depth of ore below Cumberland Plateau.—The depth to which the ore continues in a nearly vertical position in this vicinity is a matter of economic as well as scientific interest. Theoretically the beds lie in a position shown by the generalized diagram, Fig. 25, and according to the thickness of the formations above the ore where the rocks are flat or only slightly inclined the ore bed would probabiy descend to depths between 1,800 and 2,500 feet below the outcrop before it would approach a horizontal attitude. According to the structure section the axis of the syncline lies near the southeast margin of the basin, and the ore would reach its lowest altitude, referred to sea level, somewhere below the west slope of Cumberland Mountain, in Big Creek Valley. Underground, where the beds are sharply folded from a vertical to a nearly horizontal position, there is probably a much fractured

€Ok, Knox dolomite.
Oc, Chickamauga limestone.
Ob, Bays limestone.
Sr, "Rockwood" formation.
Dc, Chattanooga shale.
Cn, Newman limestone.
Cpn, Pennington shale.
Cle, Lee conglomerate.
Cbv, Briceville shale.
Cwb, Wartburg sandstone.

zone where a large volume of water would be encountered, and possibly considerable faulting, so that the extraction of the ore might be extremely difficult, if not impossible along this zone. The maximum depth to which the vertical bed of ore has thus far been profitably worked in the La Follette district is reported to be about 200 feet. There is still such a large reserve of ore above the 1800-foot level in this vicinity that it will be many years before any shaft or slope will penetrate to this depth.

According to the estimated thicknesses of the formations above the "Rockwood" iron ore, as given in the geologic section on page 142, the depth at which the ore bed in this area probably lies below the general level of the plateau developed on the Wartburg sandstone, ranges from 2,300 to 4,000 feet. Along the creeks that dissect the plateau the depth to ore would be much less. For instance, along Stinking Creek and along Laurel, Horse, Davis, and Big Creeks the ore should be reached at depths ranging from 1,500 to 3,000 feet below the surface. These depths may prove to be still less, if the thicknesses of the rocks have been overestimated.

Some observations of great value to the present discussion have recently been published by S. Whinery[1] relating to the existence of the "Rockwood" iron ore below the northwest slope of the Cumberland Plateau in southern Kentucky, about 16 miles northwest of Elk Valley, Tennessee. The information was communicated to Mr. Whinery by L. E. Bryant, of Danville, Ky., President of the Virginia Mining Company. Since the paper is short, it is quoted in full, as follows:

During the past 15 years quite an important oil-field has been developed in a region having Wayne County, Ky., as its center, and a large number of wells have been drilled in that and adjacent territory in the search for oil. Many of these wells have been carried to considerable depths below the recognized oil-bearing horizon, and one of them was drilled by Mr. Bryant at Pine Knot, a station on the Cincinnati, New Orleans & Texas Pacific Railroad, a few miles north of the point where that road crosses the Kentucky-Tennessee State line. The elevation of the surface at the crossing is about 1,400 ft. above sea-level. The railroad is located on the dividing ridge between the Cumberland river and Big South Fork. At a depth of 1,720 ft. below the surface the drill reached and passed through a formation which the drillers called "red rock," but which Mr. Bryant classified as Clinton iron-ore, as its geological position corresponded to that formation. The ore at this point was 6 feet thick and appeared to be of uniform quality throughout. An analysis of the drillings gave: Fe, 33; Mn, 0.25; SiO_2, 3; Al_2O_3, 2; CaO, 13; MgO, 7; P_2O_5, 0.333 per cent; S, trace.

This analysis seems to confirm the belief that the ore is Clinton, and that it is of a quality equal to the average of the deep or unleached Clinton ores in Tennessee and Alabama.

This discovery led Mr. Bryant to make further examinations and inquiries, and he found that the stratum called "red rock" by the drillers had been passed through and noted in the great majority of the wells carried down to the same geological horizon,

[1] Whinery, S., Clinton iron-ore deposits in Kentucky and Tennessee: Bull. Am. Inst. Min. Eng., Oct., 1912, pp. 1057–1058.

over quite a wide area in and around the oil-region. Its geological position was readily fixed in these wells, as it was noted as being from 50 to 100 feet below the Devonian black shale, which is very persistent in the region, is universally recognized and referred to by the well-drillers. The thickness of the "red rock" was not usually recorded, but was stated by the drillers to be from 3 to 6 feet.

In a number of wells reaching the horizon of the ore its occurrence was not noted. This is not surprising in view of the well-known lenticular formation of the Clinton ore-deposits in the South.

These facts seem to indicate that rich and comparatively thick deposits of Clinton ore underlie the Cumberland Plateau in this region and extend under its northern slope. If so, it will undoubtedly, in time, become commercially very valuable, particularly as the whole region is also underlain by three or four workable beds of coal, at least two of which are good coking-coal, so that both ore and coal could be mined from the same or adjacent shafts. The coal outcrops above the surface of the larger streams and is being mined in large quantitites by drifts in the region. Shafts sunk along the streams in the vicinity would reach the iron-ore at a depth of about 1,000 feet."

Shaft mining of the ore under the Cumberland Plateau in Tennessee is, however, only a remote possibility on account of the great depth at which it lies, considered together with the fact that the ore is probably not much more than 4 feet thick. In view of the drill record just referred to, as well as the basin structure of this region and the similarity between the ore beds exposed on opposite edges of the basin, it appears probable that this ore bed is continuous from Cumberland Mountain to Pine Mountain, and that an estimate of the ore tonnage is entirely possible.

Estimate of ore tonnage.—If only the area bounded by Pine Mountain and Cumberland Mountain, and extending 15 miles northeast from Fork Mountain be considered, the La Follette mines would be located about the middle of the southeast edge of this area. A solid block of ore having an average length of 79,200 feet, an average width of 47,520 feet, and an average thickness of 4 feet, would thus be indicated, making a total of 15,054,336,000 cubic feet of ore. Allowing 12 cubic feet to the ton, since the ore body includes some shale partings, and without deducting for local thinnings or for other unknown factors, the enormous quantity of 1,254,528,000 long tons of hard ore would probably represent a reasonable estimate of the reserves in this one area.

Northeast of La Follette.—Northeast from La Follette there is an almost untouched area of ore-bearing "Rockwood" formation, extending for 16 to 18 miles along the foot of Cumberland Mountain. About 11 miles of this outcrop are in the Maynardville quadrangle, the remainder being within the Briceville and Cumberland Gap quadrangles. The outcrop width of the formation ranges from about 950 feet to about 3,300 feet, according to the geologic map published in the Maynardville folio, but the width of the ore-bearing portion ranges between lower limits. The general direction of the outcrop is about N. 70° E., but the strike is sinuous owing to the re-entrant angles made by Childer, Wilson, and

Miner gaps in the escarpment. The dip of the beds here is generally moderate, their general attitude being shown in the structure section Fig. 26. Little work has been done toward mining the ore in this region on account of the great distance of the outcrop from railroad lines. No point on this outcrop in the Maynardville quadrangle was reached during the present survey, so that recent details concerning the iron ore are not available. In his description of the Maynardville quadrangle Mr. Keith says: "Iron ore is found in the form of red hematite in the Rockwood formation. It occurs interbedded with the variegated shales in layers ranging from a few inches up to three or four feet in thickness. The usual thickness is about one foot in this region. No developments have been made of ore in this locality, although much ore has been mined both to the northeast and southwest, especially under Cumberland Mountain." [1]

The writer's observations to the northeast and southwest agree with this statement. To the northeast at the Watts mine workable ore occurs with a thickness of four or five feet, as well as to the southwest at La Follette. It is probable that when transportation lines render development feasible the main ore bed will be found to be workable throughout considerable of its outcrop between these two mines.

Cumberland Gap.—The "Rockwood" formation outcrops in the foothills of Cumberland Mountain, practically all the way from Careyville northeast to the State line at Cumberland Gap. Its outcrop width is narrower toward Cumberland Gap than farther southwest. The principal development of this strip of ore-bearing formation in this vicinity and the only place examined in 1911 was at the Watts mine, about 6 miles southwest of Cumberland Gap. When visited this mine had been shut down for one year, and the slope was full of water. The ore here is reported to be from four feet to more than five feet thick, carrying a parting of

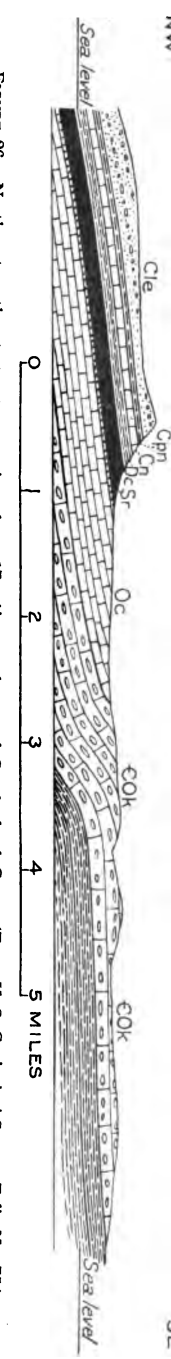

FIGURE 26.—Northwest-southeast structure section about 17 miles southwest of Cumberland Gap. (From U. S. Geological Survey Folio No. 75.) €Ok, Knox dolomite. Oc, Chickamauga limestone. Sr, "Rockwood" formation. Dc, Chattanooga shale. Cn, Newman limestone. Cpn, Pennington shale. Cle, Lee conglomerate.

[1]Keith, Arthur, Descriptions of the Maynardville quadrangle, Geol. Folio, United States, No. 75, U. S. Geol. Survey, Feb., 1901, p. 6.

shale one inch to four inches thick about two feet from the bottom. The ore in the mine is of the hard variety, and it is reported that the lower 2 feet are the best part of the bed, with rather limy ore above and partings of "jack rock" toward the top of the bed. The following section was measured in a ditch near the mouth of the slope:

Section of Watts mine 6 miles southwest of Cumberland Gap, Tenn.

(Pl. V, 13, and corresponding ore section.)

	Feet.	Inches.
Shale, sandy.		
Ore	..	3
Ore, with few knife-edge partings of shale	2	10
Shale	..	4
Ore (base concealed)	1	..

Dip 17° to 20° N. 12° W.

Total ore exposed, 4 feet 1 inch.

The inclination of the slope is reported to be about 30°, therefore it is probable that the dip of the beds becomes greater just below the surface.

According to the mine plans the ore was worked at this point from a slope about 262 feet long with four left and three right entries turned off 60 feet apart. The first left entry extended about 1,235 feet on the strike of the beds, and reached an old entry that came in from a slope on property on the southwest. The second right entry was worked for 602 feet and was still in ore. The last term of operation of this mine was from September, 1909, to October 18, 1910. A spur track about 3.4 miles in length extended from the Southern Railroad at Ore Bed Junction to the mine, and the ore was shipped to the furnace of the Virginia Iron, Coal, and Coke Company, at Middlesboro, Ky. The idleness of this furnace was responsible for the closing down of the mine. It is reported that there is plenty of ore available here and that the mine can be reopened at any time conditions in the iron trade are favorable. Other developments in this vicinity included an old slope less than a mile northeast of the Watts mine, and a number of strip-pits along the outcrop between here and Cumberland Gap.

Clinch River Valley.

In the valley of Clinch River the "Rockwood" formation occurs in two areas known as the Lone Mountains; one northwest of Maynardville and the other northeast of Maynardville. The formation contains much more sandstone and less iron ore in this area than in Cumberland Mountain, where it is largely of shale. No beds of iron ore workable for any considerable distances have been noted in the Clinch Valley area. The following facts were kindly contributed by Mr. Jas. W. Love, a student at the University of Tennessee, who made a brief investigation

of conditions in the vicinities of Loyston and Millers Ferry, Union County, under the direction of Prof. C. H. Gordon. (See map Fig. 27.)

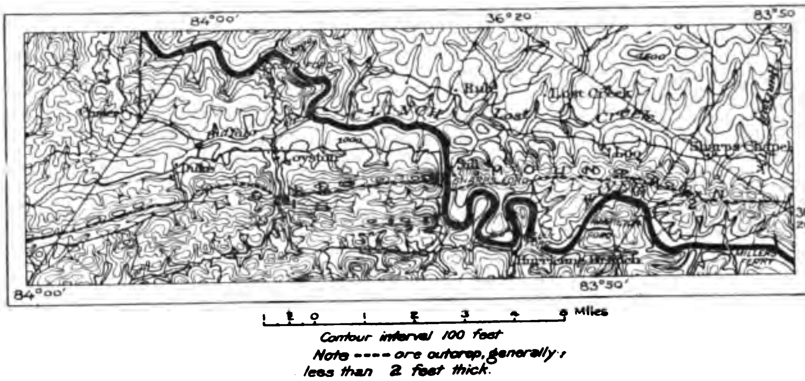

FIGURE 27.—Topographic map showing outcrops of "Rockwood" iron ore near Loyston. (Base from U. S. Topographic atlas sheets.)

Loyston.—About one mile southeast of Loyston on both sides of the road which follows a branch of Buffalo Creek through the gap in Lone Mountain, are several pits which have been opened on a bed of iron ore. This ore is reported to range from 6 inches to 18 inches thick. The ore has been used in recent years in the construction of chimneys since it breaks easily into blocks and is so soft that it may be trued with hand-saws and axes. The ore is fossiliferous and near the surface is fairly rich, the soft ore containing about 48 per cent metallic iron. (See analysis, p. 150.) The dip is 30° to 45° toward the southeast, and both the ore fragments and the overlying shale show slickensides. A series of pits or trenches have been dug on the outcrop of the ore bed for some distance from this gap along Lone Mountain. From one of these pits some ore had recently been obtained for building chimneys and the following fresh section was measured:

Section of "Rockwood" ore on Lone Mountain southeast of Loyston.

(Fig. 27, No. 1.)

Shale, yellow, crumpled.	Feet.	Inches.
Ore	1	6
Shale, hard, about	..	10
Ore	..	10
Shale.		
Total ore, 2 feet 4 inches.		

Ore from these pits is reported to have been reduced to iron in an old forge near the creek southeast of Loyston, operated by a Mr. Miller about the time of the war. Limestone from the Chickamauga was used as flux.

Millers Ferry.—(*Ousley Ford*).—The outcrops of ore in this region indicate the presence of 3 beds of ore. The oldest, No. 1, lies just south of the crest of Lone Mountain and directly above heavy beds of sandstone. The next higher bed, stratigraphically, No. 2, is separated from No. 1 by 30 to 50 feet of yellow shale. Above this bed are 40 feet of yellow shale, above which lies bed No. 3. Only one of these beds (No. 1) was measured by Mr. Love. The other thicknesses were reported to him. The following section indicates the sequence of the strata and the reported thicknesses of the ore beds here:

Reported section near Millers Ferry.

	Feet.	Inches.
Soil, soft	3 to 8	..
Iron ore, soft, fine-grained, compact, Bed No. 3 (reported)	3	..
Shale, yellow	40	..
Iron ore, soft ore, fine-grained, compact, Bed No. 2 (reported)	3	2
Shale, yellow	30 to 50	..
Iron ore, soft, fossiliferous, Bed No. 1	3	4
Sandstone.		
General dip 35° E-SE.		

An average analysis of the ore from the 3 beds indicates that the soft ore carries about 50 per cent of metallic iron, but the percentage of silica reported, 5.6 per cent, is suspiciously low. (See p. 150.) The outcrop of ore in the Loyston-Millers Ferry region is indicated on the sketch-map, Fig. 27. It is reported that a prominent steel manufacturing corporation of Pittsburg, Pa., has optioned 3,000 or more acres of land along the southern slope of Lone Mountain where the red iron ore beds outcrop, and that if a railroad is built into this district the ore may be utilized in a blast furnace to be built at a central point between here and the brown ore fields of Polk County, where this company also has options.

Resume.—Sections and Analyses.

As has been shown in the preceding descriptions there are extensive outcrops of "Rockwood" iron ore in northeast Tennessee. Most of the ore from Careyville to beyond La Follette is more that 2¼ feet thick, and at the Watts mine, below Cumberland Gap, the thickness also exceeds this figure. There is a considerable strip northeast and southwest of the Watts mine with regard to which no data were obtainable during this survey. Southwest of the Watts mine, in the northwest part of the Maynardville quadrangle the outcrop of the "Rockwood" formation is so far from a railroad that little prospecting has been done. Southwest of Elk Valley an ore bed reaching a maximum thickness of 4 feet has been observed. The outcrop in this area is badly

broken by faults. It is possible that there is a basin of ore lying deep below the Cumberland Plateau, extending from La Follette to Elk Valley, and if so, there is a vast reserve of ore in this area, not available under present conditions. Mining is at present active at La Follette on the "vertical" ore bed.

The following graphic sections and chemical analyses illustrate the character of the "Rockwood" iron ore beds in northeast Tennessee:

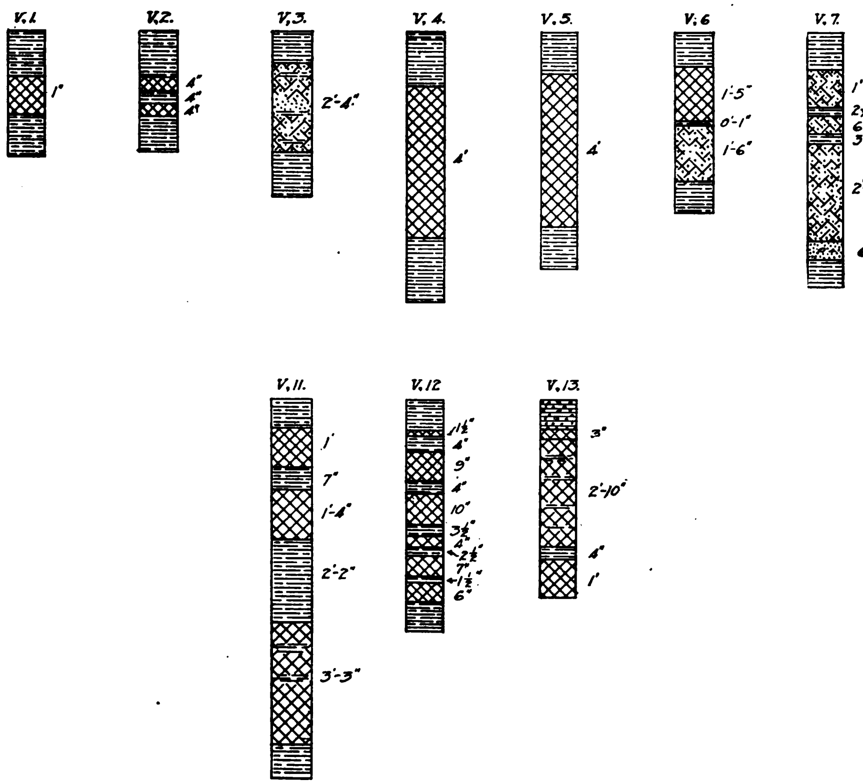

FIGURE 28.—Graphic sections of "Rockwood" iron ore beds in Northeast Tennessee.

Analyses of "Rockwood" iron ores, Northeast Tennessee.

Locality.	Authority.[1]	Fe	SiO_2	Al_2O_3	CaO	MgO	Mn	P	S	H_2O
LaFollette:										
Senaca mine—										
Hard ore..............	L	26.3	10.24	8.30	15.89	......	.60	.61	0.0	5.0
	L	32.86	6.54	......	14.05	6.75	......	......	......	......
	L	31.90	4.54	2.57	15.25	......	......	......	......	......
	L	23.80	16.76	6.90	13.75	6.06	.25	......	......	......
	L	27.80	8.56	4.10	16.70	......	.25	......	......	3.41
	L	32.50	7.52		14.45	......	......	.368	......	2.98
	L	35.10	6.46		14.40	......	......	.408	......	......
	L	31.32	8.42		15.28	......	......	.612	......	......
	L	36.40	7.82		13.30	......	......	.48	......	......
Soft ore................	L	37.50	23.34	6.28	2.70	......	......	......	......	5.0
	L	37.55[2]	10.51	6.46	5.32	......	......	1.16	......	......
	L	44.65[2]	12.48	......	......	......	......	......	......	15.32
	L	38.89[2]	12.39	6.54	3.10	......	......	.684	......	......
	L	44.95[2]	14.32	......	......	......	......	......	......	13.47
Near Loyston...............	O	48.20	8.90	11.0	......	......	0.36	......	......	......
Near Millers Ferry..........	O	50.40	5.60	......	......	......	......	0.04	......	0.5

[1]Authorities: L, LaFollette Coal, Iron and Railway Co., and LaFollette Iron Co.; O, Owners of property.

[2]Dry basis.

[3]Wet basis.

ORE IN GRAINGER SHALE.

Location.—Reports having reached the State Geologist of the occurrence of iron ore in the foothills of Chilhowee Mountain, southeast of Maryville, Blount County, a brief investigation was made of these reported deposits in October, 1911. The locality visited lies 6 to 7 miles in an air line southeast of Maryville, along "Little Mountain" or the foothills of Chilhowee Mountain, and 2 to 3 miles southwest of Little River, and is illustrated by map, Fig. 29.

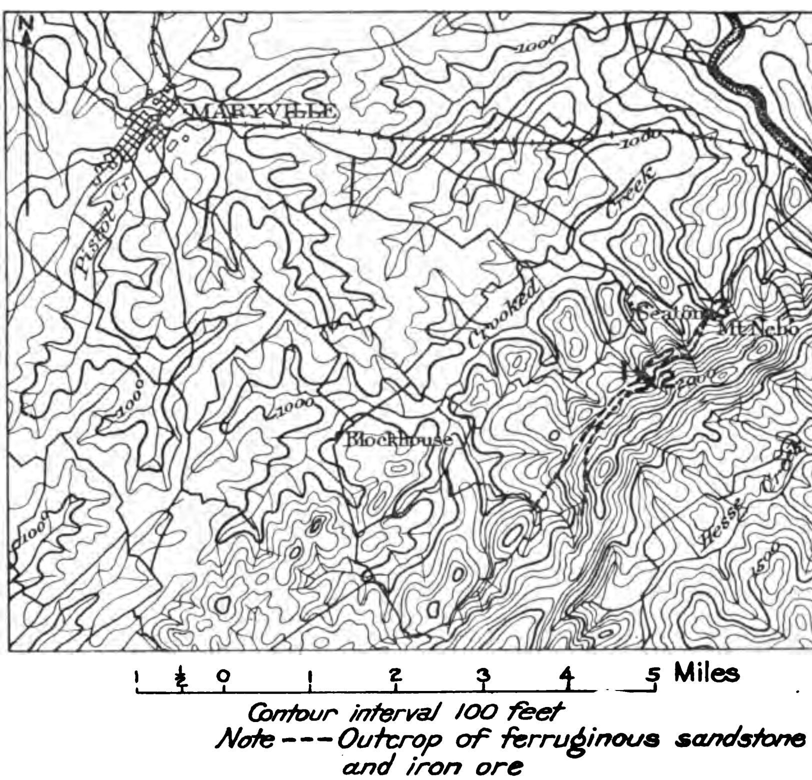

FIGURE 29.—Topographic map showing outcrop of ferruginous sandstone, ore-bearing in places, in the Grainger shale, southeast of Maryville.
(Base from U. S. Topographic atlas sheets.)

Topographic and geologic relations.—In the Knoxville geologic folio the area containing the beds in question is mapped as underlain by a syncline of Grainger shale, a formation of Devonian and Carboniferous age. The formation here consists mainly of shale and sandstone dipping southeast at low angles into the hills. Several branches flowing northwestward down the slope have cut narrow gulches through the formation at right angles to the strike of the beds and thus afforded sections across

some rather ferruginous rocks One and one-quarter miles southwest of the locality visited there is shown on the Knoxville geologic folio map, lying along the axis of the syncline, the northeast end of a narrow strip of Newman limestone, which is described as bluish, shaly, and massive limestone, of Mississippian age. The fossils collected from the ferruginous beds in the Grainger shale have been determined by Mr. E. O. Ulrich to be of Mississippian age. With regard to these fossils Mr. Ulrich has made the following statement:

"Some iron ore specimens collected by E. F. Burchard in the vicinity of Maryville, Tenn., from beds mapped as Grainger shale, contained fossils that on cursory inspection seemed to me to suggest a younger age than is commonly assigned to that formation. Further study of the material confirms this provisional determination as shown by the following partial list of fossils:

Zaphrentis cf. centralis
Glyptopora keyserlingi
Derbya keokuk
Productus aff. punctatus

and casts of numerous other bryozoa and brachiopoda, none of them materially affecting the age indicated by the named species. These, especially the Glyptopora, are highly indicative of the age of the Keokuk limestone of the Mississippi Valley—also of the Fort Payne chert of the Appalachian Valley."

Maryville locality.—About 7 miles in an air line southeast of Maryville a large prospect pit was noted in which the following section was measured. This pit is cut in the steep slope of a gap in Little Mountain through which a small creek descends, and is about 50 feet above the creek.

Section of ferruginous beds 6.4 *miles southeast of Maryville.*

(Fig. 29, 1, and corresponding ore section.)

	Feet.	Inches.
Shale and ferruginous sandstone showing concentric weathering.		
Shale, sandy, ferruginous	1	3
Ore, soft, sandy, and argillaceous	2	1
Ore, soft and shaly	..	6
Ore, tough and argillaceous	..	4
Ore, soft and shaly	..	5
Ore, soft and weathered, very fossiliferous	2	2
Shale	..	5
Ore, tough, dark red color	..	9
Shale	..	2
Ore, soft, with rich streaks and shaly streaks	2	1
Shale	..	1
Ore, soft and fossiliferous	..	4
Shale, ferruginous.		

Dip 40° S. 55° E.

Total ore, mostly lean, 8 feet 8 inches.

The material termed "ore" throughout the exposure has been thoroughly leached. It is generally soft and rather decomposed, and shows limonite specks. The softest parts are brownish and do not give a very red streak. A carload of this ore is reported to have been shipped in 1907 to the blast furnace of the Embreeville Iron Co., and to have averaged 40 per cent metallic iron. This bed is known locally as the "big seam." Analyses of this ore are given on page 154.

If the soft ore contained only 40 per cent metallic iron the hard ore would contain much less iron, since the hard ore, judging from the content of fossil remains in the soft ore that have been leached of their lime, must contain considerable calcium carbonate. It was reported that this ferruginous bed has been tested on the outcrop by 75 pits between Little River and Tennessee River, and had been found about as is shown above. There is no information at hand concerning the extent of the soft ore in the direction of dip, therefore it is not known whether the bed can be worked as a soft ore proposition or not. More light could be thrown on this question by a few drill holes, prospect slopes, and tunnels.

Between 300 and 400 yards southeast of the prospect just described, near the same creek, a prospect has been cut in another ferruginous series of beds. The stratigraphic relations indicate that these beds are higher in the formation than the "big seam," but they may, instead, represent the same beds which have been brought to the surface again by an overturned synclinal fold. At both the prospects the beds dip in nearly the same direction.

At this prospect the following section was measured:

Section of ferruginous beds 6.6 miles southeast of Maryville.

(Fig. 29, 2.)

	Feet.	Inches.
Shale, sandy, brittle.		
Ore, alternating with streaks of shale ½ to 2 inches thick....	1	1
Ore, with 3 shale partings ½ to 1 inch thick.............	2	2
Base concealed.		
Dip 52° S. 55° E.		
Total ore, about 2 feet 7 inches.		

The ore here is dark red, soft, and much similar to that in the "big seam" except that it may be slightly richer in iron.

One mile northeast from and about on the strike of the beds exposed at the pit first described, a prospect was noted in beds of hard ore. The following section was measured:

Section of ferruginous beds 6.9 *miles southeast of Maryville.*
(Fig. 29, 3, and corresponding ore section.)

	Feet.	Inches.
Ore, compact, firm, dark red, fossiliferous, contains little lime	4	9
Ore, similar to above, but parted by several thin streaks of shale	1	3
Ore, dark, hard, fossiliferous, calcareous	1	0

Dip 32° S. 55° E.
Total ore, about 6 feet 9 inches.

The material is jointed, and when struck with a hammer tends to break into small blocks with nearly rectangular faces. This prospect is reported to have been made in 1908, but there was very little debris in it on account of the opening being situated on a steep hillside, some 25 feet above the creek. Where this bed passes below creek level another pit had been cut, but this was full of debris at the time of visit.

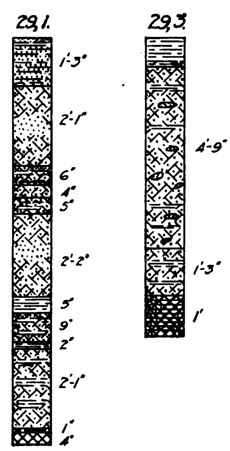

FIGURE 30.—Graphic sections of iron ore beds in Grainger shale, southeast of Maryville.

Analyses of iron ore from near Maryville.

Locality.	Authority.[1]	Fe	SiO_2	Al_2O_3	CaO	MgO	Mn	P	S	H_2O
Maryville District.										
Soft ore:										
Seam No. 1, bottom	T	36.14	26.50	9.81	......	......	......	.15	......	......
Seam No. 1, middle	T	40.21	18.40	8.72	......	......	......	.14	......	......
Seam No. 1, top	T	34.90	22.00	10.13	......	......	......	.16	......	......
Seam No. 2	T	40.41	18.40	8.95	......	......	......	.14	......	......
Do	T	39.90	20.00	9.20	......	......	......	.24	......	......
Do	T	38.99	23.50	9.79	......	......	......	.16	......	......
Do	T	35.02	24.20	10.21	......	......	......	.19	......	......
Do	T	41.43	19.00	9.37	......	......	......	.15	......	......
Do	T	10.68	61.00	13.14	......	......	......	.06	......	......
Hard ore	O	35.00	13.70	6.95	12.03	1.40	.30	.24	......	......
Soft ore	O	41.00	20.52	10.00	.93	.49	.28	.21	......	......
Do	US	33.47	38.29[2]		none	......	......	0.10	0.02	......
Hard ore	US	33.47	25.58[2]		11.12	......	......	0.09	0.07	......
Soft ore	C	45.10	12.88	5.75	......	......	......	......	......	......

[1]Authorities: C, Citico Blast Furnace Co.; T, T. C. & I. R. R. Co., Ensley, Ala., 1907; O, Owners of property; US, U. S. Geological Survey.
[2]Insoluble.

MINING NOTES.

Stages of development.—As elsewhere in the Southern Appalachians, the development of mining bedded iron ore in East Tennessee has occurred in two principal stages. The first stage consists of mining the ore on the outcrop (see Pl. XIII), and the second stage consists in mining it from underground drifts and slopes. Open cut mining has been carried on along the outcrop practically wherever the ore has been found thick enough to be dug and shipped to market without entailing financial loss. Only in areas remote from the railways, or where the ore is very thin, are there no traces of former stripping operations. Stripping of the ore beds was done by hand, and by scrapers drawn by horses or mules, and was carried to as great depth as was found to be profitable, depending upon the thickness and quality of the ore bed, its dip, and on the character of the overlying rock. A maximum thickness of 30 feet of stripping was observed at one place. Where unweathered the overlying shale is often found to be so hard that it is necessary to blast it out, after which the loosened material is shoveled into wagons and hauled away. Few of the old strip pits now show their former maximum depth since they are partly filled by slumping down of the walls, and in many cases the shale has been "back filled" where the ore was removed. This phase of the iron mining industry is now practically obsolete, except at some of the workings in the Chamberlain-Barnardsville area, because of the exhaustion in other areas of the reserves of soft ore near the surface. Some of the old trenches and embankments that are encountered in the the woods while following the outcrop of the ore beds are of considerable age, as is indicated by the size of the forest trees that have grown over them since mining was abandoned.

Underground mining has succeeded surface mining generally where the ore beds are of attractive quality and of more than the average thickness, or else where they are so situated that the cost of transportation to blast furnaces is relatively low. This does not necessarily imply that the ore is now being mined underground at all the localities at which it is available, but many of the choicest localities containing outcrops of "Rockwood" ore in Tennessee are now under development. The localities in which underground mining is at present in progress are the Euchee area, the Rockwood-Cardiff area, and the Chamberlain area, all in central East Tennessee, and the La Follette area in northeast Tennessee, and mining has only temporarily been suspended in the Cumberland Gap area in northeast Tennessee.

Considerable ore for iron making has been obtained from underground workings at Hill City, but these workings were mainly for soft ore and have been abandoned for 5 or 6 years. Near Ooltewah drifts have been driven underground for paint ore.

Mining the iron ore underground, in the outcrop areas in East Tennessee is generally not so simple as it is along Red Mountain in the Birmingham, Alabama, district, on account of the more complicated structure of the formations in Tennessee. In the Birmingham district the dip of the ore bed from its outcrop generally to distances of 1,500 to 2,500 feet continues fairly uniform, ranging generally from 15° to 45°, but averaging less than 30°. Beyond the distances just mentioned there is a zone of small faults in which the ore is displaced from 15 to 300 feet, and beyond this fault zone there is a wide extent of gently dipping or undulating beds. In East Tennessee, in the foothills of Cumberland escarpment, in localities where the ore bed is thick enough to be mined, it is in many places faulted and much folded close to the surface, as is noted in the description of the Rockwood-Cardiff area (page 113). At La Follette the ore bed is in a nearly vertical attitude, and as is indicated by the various notes on outcrops the dip is extremely variable throughout the State, varying within short distances from gentle normal northwest dips to steep overturns toward the southeast. This irregularity of structure naturally complicates mining more or less, and should tend to make the cost of extraction of ore higher than in areas where a mine can be laid out on a symmetrical plan such as is possible in the Birmingham district. In Tennessee many of the mines must follow a special plan which has to be developed as the mine is driven deeper, in order to solve the unexpected problems that are caused by structural irregularities. Some notes on the plans followed in the Rockwood-Cardiff, Euchee, and La Follette areas have been given in the descriptions of those areas, and it was hoped that some drawings of mine plans might be obtained from the mining companies for use in this bulletin, but this has proved impossible.

A further stage to which mining of bedded iron ore may eventually progress is that of shaft mining. This would probably be the most practicable method of working the ore below the Cumberland Plateau, if it is ever mined there. In the area between La Follette and Elk Valley and also northwest of the Rockwood-Cardiff strip, the ore is probably of workable thickness, although very deep below the surface, as has been shown in another portion of the text. No shaft mining of red iron ore has yet been attempted in the South, but it is reported that a shaft is soon to be sunk to an ore bed 1,900 feet below the surface near Oxmoor, Alabama, and the results of this work will be

CHAMBERLAIN, TENNESSEE—FACE OF UPPER BENCH OF "ROCKWOOD" HARD ORE AT OPEN CUT OF ROANE IRON COMPANY MINE. PERSONS STANDING ON TOP OF ORE BED.

Photo by E. F. Burchard.

watched with close attention by every one interested in the development of Southern iron ore fields.

The red iron ores of East Tennessee have been mined and utilized for the manufacture of iron for more than half a century. Safford[1] notes that as early as 1854 there were 5 small blast furnaces working almost exclusively on "dyestone," or "Rockwood" red hematite. These furnaces were located at Cumberland Gap and Crockett's, Claiborne County; Sharps, Grainger County; Eagle, Roane County; and Bluff (Chattanooga), Hamilton County. These furnaces, it will be noted, were all situated close to the outcrop of the ore. In the furnace at Crockett's brown hematite also appears to have been used as part of the charge. In addition to these furnaces, in two of which the blast was created by steam power, the rest by water power, there were at that time fifteen bloomaries, or forges, distributed through Hancock, Claiborne, Campbell, Anderson, Roane, and Rhea counties, all of which used the "Rockwood" hematite for making bar iron. In other parts of the State the brown ores were the principal source of iron and were worked in fifty or more localities.

Conditions affecting underground mining.—A summary of the most important points to be considered in relation to underground mining of bedded iron ore in the South would include: (a) Thickness of beds; (b) quality of ore; (c) attitude and structure of beds; (d) relation to topography and water level; (e) continuation of ore with depth; (f) distance from transportation routes; (g) relation to markets.

The question of markets in the area under consideration is not at present serious, since most of the blast furnaces noted on pages 165 and 166 are, when in blast, willing to buy ore at market prices.

With regard to the minimum workable thickness, the poorest acceptable quality, and the other limitations that may be imposed by the various factors mentioned above, it may be said that all are more or less interdependent. For instance, a very rich ore can be worked in thinner and more disturbed beds than can a lean ore. A rich and thick ore bed whose extent is known to be limited by a fault may not warrant the outlay necessary for a railway spur and the necessary mining equipment, which a thinner and leaner bed whose extent has been proved by prospecting to be much greater might warrant. Except in the case of the ore beds near Ooltewah, which are worked in a small way for paint material, the writer has observed in the Southern region no extensive underground mining of beds whose thickness averaged less than 2 feet, nor does self-fluxing ore carrying less than an average of 25 per cent of metallic iron, seem to be considered minable. In fact, no one acquaint-

[1]Safford, James M., A geological reconnaissance of the State of Tennessee: Tennessee Geological Survey, 1856.

ed with iron-making in the South would at present be likely to become enthusiastic over mining a 2-foot bed of ore averaging 25 per cent of metallic iron, no matter how extensive or easily accessible it might be. With changing conditions, however, such an ore bed may become fo considerable value at some future time, and for this reason it was thought best to include mention of the outcrop of such beds in the present bulletin.

As to the maximum distance down the dip, measured from the outcrop, or the maximum vertical depth below the level of the outcrop, to which an ore bed may profitably be worked, it should also be stated that these limits are greatly affected by other factors. In some slopes where the ore is thin, or of poor quality the limit of workability under present conditions has already been reached, and mining has been discontinued. Probably when the prices of ore have risen sufficiently some of these slopes may be reopened. Other slopes that are driven in fairly thick ore of good quality have penetrated far beyond the abandoned slopes and are still being operated at a profit. Obviously no workable limit can be applied to ore in such localities. For the purpose of making hasty approximations as to the tonnage of iron ore available in various parts of the United States in 1908,[1] a vertical depth of 1000 feet was taken as an arbitrary limit to which the bedded iron ore in East Tennessee might be considered available under conditions prevailing at that time. No active slope had then reached more than half that vertical depth and some had been abandoned at much less depths. Although less than five years have elapsed since the above mentioned estimates were made, one would now hesitate to place a workable limit at 1,500 feet, or even at 2,000 feet vertically below the surface. It is therefore evident that the workable limit of ore in depth is a rapidly progressing factor, and one which can not be assumed with any degree of certainty in making estimates of ore reserves.

The question has often been asked as to what extent surface conditions could be depended upon to indicate the thickness, quality, continuity, and structure of the ore bed beneath the surface. Surface conditions in regard to the quality of an ore bed, provided it has been prospected back to the hard ore, are generally reliable. If prospect pits extending a sufficient distance along the outcrop have disclosed hard ore of uniformly good quality it may reasonably be assumed that the bed will continue below the surface with but little deteroriation. A few exceptions to this rule have, however, been noted. The variations in quality and thickness along the outcrop should be carefully noted. Variations are characteristically more abrupt in the direction

[1]Hayes, C. W., Iron ores of the United States—Papers on the conservation of mineral resources: Bull. U. S. Geol. Survey No. 394, 1909, pp. 70–113.

of the dip than along the strike of the ore beds. The structure of the beds overlying the ore should be noted carefully, since there naturally exists a certain parallelism in structure between surface and underlying beds. Faults or dislocations in the strata should be carefully noted, and it should at once be determined whether the beds beyond the fault have moved relatively up or down. If those beds have moved upward, was the upthrow sufficient to bring the ore bed above the surface and thereby terminate its extent in that immediate vicinity? If the rocks beyond the fault were dropped, instead, to what depth is the ore depressed? To what depth has the ore dipped below a given point on the surface?

These questions can perhaps be answered by careful geological study, but it may require deep drilling to definitely settle such points. The writer has in mind an instance where, had the geological evidence been given due weight much expense and futile search for ore might have been avoided. At the outcrop the ore dipped at a moderate angle, and conditions were evidently favorable for the driving of a slope, but a few hundred feet beyond the outcrop, in the direction of the dip, an abrupt change occurred in the surface rocks. An area of nonfossiliferous chert and dolomite which lay above the iron ore adjoined a highly fossiliferous chert. The fossiliferous beds were those of the Fort Payne chert, which normally lie 150 to 200 feet above the iron ore; the nonfossiliferous ones were those of the Knox dolomite, which normally lie many hundreds of feet below the ore. No attention was paid to these geological conditions, but a slope was driven and elaborate preparations were made for mining. Within a few hundred feet the slope ran into broken ground and the ore was lost. Two other slopes were driven, both of which encountered the same difficulties. The conditions were plain enough, but instead of heeding them the owners drilled an unnecessary hole nearly 1,000 feet deep in search of the ore in the chert of the Knox dolomite. Thorough deep drilling—in the right place—is most strongly recommended. Too little drilling has thus far been done in the ore fields, probably because of the great expense, but the expense is generally well justified by the information yielded concerning depth, thickness, and quality of ore, dip of the beds, etc., provided a preliminary geological study is made so that the drill hole is judiciously located.

The great extent to which the soft ore beds were formerly worked at the surface is one of the factors that has led to the greatest misapprehension concerning Southern iron ores in general. To persons engaged in pursuits wholly unrelated to mining but who may be interested in mineral lands from the surface of which there was produced twenty to fifty years ago a considerable tonnage of rich ore, it naturally appears reasonable to believe that this mining activity should at some future

time be revived. It should be necessary only to recall two points in this connection; first, that surface mining is the cheapest method of working the ore beds. It requires comparatively little outlay for equipment, and it can be terminated and the outfit moved away without great loss when the work becomes unprofitable. Second, the soft ore, which was obtainable at the surface, was much richer in metallic iron than the hard ore which is to be expected below groundwater level. If these two points are borne in mind it will readily be seen that to be workable underground an ore bed must have a thickness much greater than the 6-to-18-inch seams that were once stripped and trenched for many miles along their outcrop in East Tennessee.

Concentration of ore.—With the gradual depletion of the highest grade of iron ore reserves in all countries, increasing attention is being paid to the possibilities of beneficiation of lower grades of ore. Beneficiation of iron ore in the Lake Superior District is being accomplished by means of extensive plants for washing, concentrating, roasting, nodulizing, and briquetting ores at various places in Minnesota, Michigan, and Wisconsin.

In the South the best known process of beneficiating iron ores is that applied to brown ore by crushing, washing in a log washer, screening the washed material, and picking the oversize on a picking belt. Just why some similar methods of treatment were not until recently applied to the betterment of the shaly grade of red iron ores it is difficult to understand, in view of the success that has attended certain efforts in this direction in Tennessee and Alabama within the last three years. In mining a 4-foot bed of "Rockwood" ore with thin shale partings, aggregating only 4 inches in thickness, over 8 per cent, by volume, of shale is shot down with the ore, to which must be added more or less roof shale. In many places the total percentage of shale is probably not less than 20 per cent, and it is difficult underground to separate this broken shale from the ore, consequently most of it is hauled to the surface, and if not separated at the tipple goes on to the blast furnace. At the mines of the Brown Mining Company in the Rockwood-Cardiff area picking tables have been given a practical trial extending over a period of three years. The results as gauged by analyses of the picked ores compared with analyses of the ores delivered prior to the installation of the picking tables are reported to have shown that carefully picked ores are of better grade. Gains in the average percentages of metallic iron and decreases in the average percentages of silica are apparent. Similar results are reported from operations at a mine in northeastern Alabama where the ore contains a considerable percentage of shale in the form of irregular seams and nodules.

Interesting experiments have been made recently in a commercially equipped private laboratory at Wilmington, Delaware, in the concentration of iron ores by the Moxham-du Pont Haloid Process. In this process the ore is ground to pass 100 mesh screens, and is fed into troughs containing haloid solutions of high specific gravity in which the tailings float. Separation is thus effected of the lighter siliceous impurities from the heavier iron oxide concentrates. As affecting the hematites three tests were made of siliceous Alabama ore carrying 34.32 per cent of iron and 44.80 per cent of insolubles, and therefore not of workable grade. Upon treatment this ore yielded concentrates ranging from Fe, 41.10; insolubles, 34.50 to Fe, 53.32 and insolubles, 16.90. The richer the concentrates the smaller their quantity. In the first instance there were 81.2 per cent of concentrates yielded, and in the last instance 48.8 per cent, but the efficiency in the last instance is 97.2 per cent as compared with 75.7 per cent in the first trial. It is reported that this process can be carried on economically, and if so, there would appear to be a great opportunity for its application in conserving large quantities of siliceous and shaly red iron ores in the Southern States.

A series of experiments in concentrating Alabama red hematite was made by Wm. B. Phillips[1] in 1895-1897. Soft, red ore containing high percentages of silica in the form of fine to coarse grains and small pebbles was crushed and screened with the result that the percentage of iron oxide was materially increased. Considerable increases in the percentage of iron oxide were also produced by crushing and screening the ore and feeding the screenings to a magnetizing machine. As to the results, Mr. Phillips says:

> "These tests were * * * made on carload lots of ore and extended over several months. Conditions as to fineness of material treated, speed of the machines, amperage, and voltage used and character of the raw material were such as to give a range of observation. The conclusions reached were that it was entirely feasible to make concentrates of 50 per cent of iron and above from ores that were worthless for the blast furnace, and the yield of such concentrates would be not less than 50 per cent by weight of the raw ore. The extraction of the available iron in the raw ore was about 85 per cent. In some important instances the yield of workable concentrates was about 60 per cent of the raw ore treated, an ore otherwise worthless."

Similar tests were also made on limy red ores with the result that they were generally improved.

Although none of these special processes have yet been put into commercial application there is the possibility that they will some time be commercially successful. It is of interest to know what would be the result of treating ore containing a large proportion of shale inter-

[1]The results of this work are reviewed by Mr. Phillips in "Iron Making in Alabama," 3rd edition, 1912, pp. 102–112.

laminated with the hematite, since this type of ore is common in the vicinity of Chattanooga, on both sides of the State line.

LIMESTONE FOR FLUX.

General statement.—No especial search was made for fluxing material during the present investigation of the red iron ores, since it is a matter of common knowledge that good limestone is vastly more abundant in East Tennessee than ores of iron. Since it may be of interest in connection with the description of the red ores it has been decided to summarize here some of the existing information relating to the limestone formations of East Tennessee. The following systematic discussion is adapted from a paper by E. O. Ulrich on the Portland Cement Resources of Tennessee.[1] In the search for limestone suitable for the manufacture of Portland cement, although magnesian limestone is excluded from consideration, a great deal is learned concerning limestones of all kinds and such knowledge is often of service in locating deposits for other commercial purposes. Several other papers in which Tennessee limestones are described have been published recently by C. H. Gordon,[2] and to these papers as well as to that by Mr. Ulrich the writer wishes to express his indebtedness for chemical analyses and other data.

The requirements of hard limestone for fluxing purposes, so far as quality is concerned, appear to be simple, viz., that the rock shall be as free as possible from materials other than calcium carbonate and magnesium carbonate. Unless it is desired to produce a magnesia-free slag for use in Portland cement-making, there is no objection to the fluxing rock carrying a high percentage of magnesium carbonate—indeed, some blast furnace men prefer to use high-magnesium limestone and even dolomite instead of high-calcium stone. On the other hand argillaceous limestones, or those that contain an appreciable percentage of silica and alumina are unfit for use in the blast furnace, since the function of the limestone is to combine with the silica and alumina in the coke and ore and carry it into the slag.

Cambrian limestones.—Limestones form but a small part of the Middle Cambrain rocks in Tennessee. Certain layers of the Maryville limestone probably carry a higher percentage of calcium carbonate than any other Cambrain limestone in the State. Other limestone beds, ranging in thickness from a few feet to nearly 400 feet, have been described under the names of Beaver and Rutledge limestones. Others again, are included as calcareous members in the Nolichucky shale and the Conasauga shale.

The great bed of Knox dolomite overlies these Middle Cambrian formations. The lower half of the Knox is of Upper Cambrian age and the upper half is of Ordovician

[1]Bulletin U. S. Geol. Survey No. 243, 1905, pp. 301–307.
[2]Gordon, C. H., The Marbles of Tennessee: Bull. Tennessee Geol. Survey No. 2-D., 1911.
——— Cement materials in Tennessee: The Resources of Tennessee, Aug., 1911, pp. 58–69.
——— Cement materials in East Tennessee: The Tradesman, Dec. 12, 1912, pp. 32–33.

age. So far as known, the percentage of magnesia in the 3,500–4,000 feet of limestone comprised in the formation is everywhere rather high.

Ordovician limestones.—The Ordovician formations of the eastern part of the Great Valley have been described in folios and other publications of the United States Geological Survey under several local names. The relations of these formations to one another are approximately as follows:

Sevier shale.
Tellico sandstone.
Moccasin limestone .... } Athens shale.
Chickamauga limestone (including Holston marble lentil) . . }

At the base is a rather persistent bed of more or less argillaceous limestone (Chickamauga), the thickness of which varies greatly, reaching in places several hundred feet. It corresponds in position, and in a considerable degree also in lithologic character, to the Ordovician limestones used for cement making in the more notrhern part of the Appalachian Valley. It outcrops in bands that lie approximately parallel to the margin of the valley. Near the eastern edge of the valley, where the limestone is thin and locally absent, the overlying black shale (Athens) is thicker.

In places heavy beds of red and gray marble (Holston marble lentil) occur in the Chickamauga limestone. This marble is generally a very pure limestone, being especially low in magnesia, but in places is rather high in iron oxide—an ingredient which should add to its value as fluxing material.

Similar and in places extensive beds of crystalline and other limestones occur locally in the Sevier shale. Such limestone beds are especially well developed in the bands striking southwest from Knoxville to Athens. Thinner and more earthy beds of limestone occur, though less commonly, in the Athens shale. In the region between Holston and Clinch rivers the Chickamauga limestone is generally overlain by the Moccasin limestone, a reddish argillaceous limestone several hundred feet thick.

The Ordovician limestones of the western half of the valley are all included in the Chickamauga limestone, a great mass of rocks, aggregating from 1,200 to 2,000 feet in thickness, consisting almost entirely of limestone. Locally and in certain parts of the section, especially toward the top, the limestone becomes shaly, or it may include many thin beds of shale. Though the greater part of the formation may be classed as a pure limestone, it is nevertheless true that many layers contain considerable clayey matter and a few are siliceous and on decomposing give rise to chert. The percentage of magnesia, however, is almost everywhere low, although analyses establishing the fact are wanting. In the vicinity of Chattanooga the lower half of the formation carries highly argillaceous limestones, generally mottled with red.

Mississippian limestones.—Non-magnesian limestones occur in three Mississippian formations in Tennessee. The lowest of these is the Fort Payne chert, in which the limestones are prevailingly very siliceous and cherty, and for this reason are probably not of importance in this connection. Outcrops of the Fort Payne occur in the east side of the Cumberland plateau as far north as Pickett County.

In eastern Tennessee the Mississippian rocks above the Fort Payne chert are divided into the Pennington shale at the top and a limestone formation below. To the north the latter is called Newman limestone, having been traced from the Newman area in southwestern Virginia, and to the south is called Bangor limestone, being there continuous with the Bangor limestone of Alabama. The limestones in the Pennington are generally local, very little limestone appearing in the formation.

Limestones utilized.—The formation in which the largest number of quarries are operated for fluxing stone is the Bangor limestone. At South Pittsburg this limestone was formerly used for flux, but since the closing down of the blast furnaces the rock has been utilized in the manufacture of Portland cement. Near Chattanooga and near Spring City the Chickamauga limestone has yielded stone for flux. Near Ooltewah, Daisy, Dayton, and Rockwood the Bangor limestone is quarried for flux, and near La Follette the stone is of practically the same age as the Bangor but is here called the Newman limestone. (See Pl. XIV.)

The following analyses indicate the essential chemical composition of the principal limestones of the State that are of value as blast furnace flux:

Limestone analyses.

Location.	Formation Symbol.	Authority.	Silica (SiO_2) Per ct.	Aluminum oxide (Al_2O_3) Per ct.	Ferric oxide (Fe_2O_3) Per ct.	Calcium oxide (CaO) Per ct.	Magnesium oxide (MgO) Per ct.	Carbon dioxide (CO_2) Per ct.	(H_2O)	Other minerals.
Knoxville......	Ohl	L. G. Eakins.......	0.17	0.04	0.23	55.47	0.30	43.63	0.21	......
Hawkins Couny	Ohl	A. L. Colby........	0.13	trace	0.26	55.32	0.21	43.51	0.125	S..005
Knoxville......	Ohl	Univ. Tenn. Ex. Sta.	0.07		[1]0.21	55.12	0.51	43.98	......	......
Meadow.......	Ohl	G. S. Jamieson.....	0.23	0.16	0.08	55.87	0.15	43.47	......	......
Kingsport.....	Oc	S. Henry Harrison..	0.58	0.86		54.87	0.81	[2]43.04	......	......
Citico dolomite.	?	Roane furnace.....	1.04	......	......	33.36	18.47	46.52	......	......
Mission Ridge..	Oc	Roane furnace.....	4.82	2.50	......	49.91	......	......	......	......
Spring City....	€Ok	Dayton C. & I. Co .	10.30	3.40		28.84	16.18	......	......	......
Spring City....	?	K. K. Stevens......	4.42	1.82		51.36	1.60	......	......	......
Spring City....	?	K. K. Stevens......	8.80	2.01		48.78	1.38	......	......	......
Chickamauga..	Oc	Citico furnace......	2.78	1.74	......	51.38	......	......	......	......
Knoxville......	Ol	L. & N. R. R	......	[3]2.07	......	53.53	1.12	43.29	......	......
Straw Plains...	?	Chemist, Jeffrey Mfg. Co........	5.38	0.58		30.95	18.33	44.49	......	......
South Pittsburg	Cb	Hunt Engineer. Co .	1.20	0.8	......	54.14	0.52	......	......	......
Daisy.........	Cb	E. T. Leonard.....	0.40	0.48	......	54.28	0.94	[4]43.90	......	......
Daisy.........	Cb	Citico furnace......	1.74	0.78	......	53.54	0.59	......	......	......
Graysville.....	Cb	....	1.30	0.92	......	52.85	1.45	[4]43.48	......	......
Dayton.......	Cb	Dayton C. & I. Co .	2.90	0.80		51.69	1.86	......	......	......
Rockwood.....	Cb	Roane furnace.....	1.12	1.13	......	53.35	1.19	43.23	......	P 0.16
Rockwood.....	Cb	Roane furnace.....	3.44	1.94	......	51.42	0.13	40.45	......	......
										Other oxides.
Rockwood.....	Cb	Roane furnace.....	1.04	......	......	53.06	1.70	......	......	.68
Rockwood.....	Cb	Roane Iron Co.....	0.56	......	......	53.36	1.80	......	......	.44
Rockwood.....	Cb	Roane Iron Co.....	0.38	......	......	52.66	2.40	......	......	.52
Rockwood.....	Cb	Roane Iron Co.....	0.68	......	......	51.92	2.80	......	......	.72
Rockwood.....	Cb	Roane Iron Co.....	2.92	......	......	48.81	4.00	......	......	1.52
Rockwood.....	Cb	Roane Iron Co.....	2.40	1.24		48.10	4.91	......	......	......
Cumberl'd Gap.	Cn	Univ. Tenn. Ex. Sta.	6.60	0.77		49.20	2.28	......	......	......
LaFollette.....	Cn	LaFollette Iron Co..	3.20	1.88	......	51.00	1.12	42.80	......	......
Arthur........	Cn	Va. I. C. & C. Co...	1.38	1.10		53.20	1.14	43.06	......	......

[1]Fe_2O_3 FeO. [2]Loss by ignition. [3]$Al_2O_3+SiO_2+Fe_2O_3$. [4]By difference.

A, Chamberlain, Tennessee—General View of Stripping Operations at "Rockwood" Ore Mine of Roane Iron Company.

Photo by E. F. Burchard.

B, La Follette, Tennessee—Fluxing Stone Quarry in Newman Limestone, Operated by La Follette Iron Company.

Photo by E. F. Burchard

A, CHATTANOOGA BLAST FURNACE, SOUTHERN IRON AND STEEL COMPANY, CHATTANOOGA, TENNESSEE.

Photo by Wilbur A. Nelson.

B, CITICO BLAST FURNACE, CITICO BLAST FURNACE COMPANY, CHATTANOOGA, TENNESSEE.

Photo by Wilbur A. Nelson.

NOTES ON THE IRON INDUSTRY.

Blast furnaces.—There are six blast furnace establishments with a total of nine coke stacks in East Tennessee that were built to use the red hematite ores of the State. All these furnaces except the two stacks at South Pittsburg are in a state of activity at present. In addition to the red iron ore these furnaces generally use some limonite (popularly termed brown hematite in this locality). The blast furnace charge thus consists of red hematite, limonite, coke, and limestone (or dolomite). The proportions of the burden vary greatly not only between the various furnaces but from time to time in the practice of the same furnace. Those furnaces which control an adequate and steady supply of iron ore are of course able to maintain more uniform operations than those which must purchase ores in a shifting market.

There are no recent data available on blast furnace practice in Tennessee, therefore, no exposition of this interesting subject will be attempted here. Conditions are somewhat similar in northern Alabama, and for recent data on the subject from that area, the reader is referred to a report by the Alabama Geological Survey.[1]

A list is given below of the blast furnaces in which red hematite ore is reduced. The notes on capacity and coke ovens are taken from the directory of the American Iron and Steel Association for 1908, with supplement for 1912.

BLAST FURNACES IN EAST TENNESSEE, USING RED IRON ORES.

Chattanooga furnace Southern Iron & Steel Co., Chattanooga.

One coke stack; ores, red and brown hematite from Georgia and Alabama; product, foundry, forge, and other pig iron; annual capacity, 68,000 tons. Active in 1912.

Citico furnace: Citico Furnace Co., Chattanooga.

One coke stack; ores, Tennessee and Georgia red and brown hematite; product, forge and foundry pig iron; annual capacity, 40,000 tons. Active early in 1911, but idle 1912.

South Pittsburg, Nos. 2 and 3, furnaces: Tennessee Coal, Iron & Railroad Co., South Pittsburg.

Two coke stacks (fuel made by company); ores, brown hematite from Georgia and hard red fossiliferous hematite from the Tennessee

[1]Phillips, Wm. B., Iron-making in Alabama, 3d edition: Alabama Geol. Survey, 1912, 254 pp.

mines of the company; product, foundry and forge pig iron; total annual capacity, 110,000 tons. No. 2 last active in July, 1904, and No. 3 in November, 1905.

Dayton furnaces: Dayton Coal & Iron Co., Ltd., Dayton.

Two coke stacks; ores, Tennessee fossil and Georgia hematite partly mined by the company; product, foundry, forge, and other pig iron; total annual capacity, 90,000 tons. Connected with the furnaces are 375 coke ovens with an annual capacity of 120,000 net tons. Active in 1912.

Rockwood furnaces: Roane Iron Co., Rockwood.

Two coke stacks; ore, red, fossiliferous hematite partly mined by the company; product, foundry, forge, and other pig iron; total annual capacity, 100,000 tons. Connected with the furnaces are 370 coke ovens with an annual capacity of 167,400 net tons. Active in 1912.

La Follette furnace: La Follette Iron Co., lessee, La Follette.

One coke stack; ores, red fossiliferous and brown hematite partly mined by the company; product, foundry, forge, basic, and other pig iron; annual capacity, 80,000 tons. Connected with the furnace are 342 coke ovens with an annual capacity of 145,000 net tons. Active in 1912.

In addition to the blast furnaces in Tennessee mentioned above, the furnaces at Middlesboro, Kentucky, described below, are of interest since they have in the past furnished a market for Tennessee iron ores.

Watts furnaces: Virginia Iron, Coal and Coke Company, Middlesboro, Kentucky.

Two coke stacks; ores, brown and red hematite from Tennessee and Virginia; product, foundry, forge, and other pig iron; total annual capacity, 110,000 tons. Idle in 1911 and 1912.

These furnaces utilized "Rockwood" ore from the Watts mine near Arthur, and brown ore from Ducktown, Tennessee, and from points in Virginia.

Possibility of Steel Manufacture.

The desirability of utilizing in the vicinty of Chattanooga, Tenn., the products of Southern blast furnaces has long been realized by the foremost iron makers of the South, and according to Killebrew[1] the Roane Iron Co. possessed at Chattanooga, as early as 1881 a Siemens-

[1]Killebrew, J. B., Iron and Coal of Tennessee: Tennessee Commission of Agriculture, Statistics, and Mines, 1881, p. 92.

A, Dayton Blast Furnace, Dayton Coal and Iron Company, Dayton, Tennessee.
Photo by Wilbur A. Nelson.

B, Rockwood Blast Furnace, Roane Iron Company, Rockwood, Tennessee.

Martin (open-hearth) plant for making steel, and was engaged in making steel and iron rails, and in re-rolling old rails, but there are not now any steel plants operating in this vicinity.

There are no longer any serious obstacles in the way of making steel from Southern iron ores so far as the character of the ore is concerned, as is shown by the successful operations of steel plants at Ensley and Gadsden, Alabama, and Atlanta, Georgia. The possibilities of Chattanooga as a steel making center are now engaging the attention of owners of iron and coal lands, technical experts, and capitalists, and it is to be hoped that a plan may be evolved whereby the great advantages of Chattanooga as a manufacturing and distributing center may be grasped and still further developed by the addition of steel mills.

Certain comprehensive reports by mining engineers and metallurgists on an assemblage of iron ore, coal, and timber properties situated within a short radius of Chattanooga in Tennessee, Georgia, and Alabama, have been placed at the disposal of the writer. According to these reports it is considered feasible to utilize the raw materials at Chattanooga and to carry the manufacturing process to the last stages of the finished iron and steel products. These reports cannot be reproduced here, nor can the details upon which their conclusions are reached be quoted, but a few of the essential points favoring Chattanooga as the logical location for a steel plant that are emphasized in a comprehensive paper already published[1] on the subject may be properly mentioned here:

(1) Ore resources. It is considered that there is sufficient ore available in the district to warrant the establishment of a steel plant. In arriving at this conclusion the large quantities of available ore, low in iron and silica, and high in lime have been included, as well as limited supplies of high grade siliceous red and brown ore. The greater part of the available red ore should be mined at a reasonable cost per unit of iron.

(2) Coal resources. The coking-coal resources are considered adequate, although, owing to the irregularities of the local coal beds both as to thickness and quality, the coal fields of eastern Kentucky and southwestern Virginia are also figured into the general estimates,

(3) Cost of pig iron production. This is the critical factor in steel manufacture. The cost of making pig iron under the most favorable conditions would probably be somewhat higher here than in the Birmiugham district, where it is made most cheaply in the South, but it is considered that the costs should not exceed those at Birmingham by more than $1.20 per ton. The average cost at Birmingham is taken at

[1]Porter, John Jermain. The Steel making Resources of Chattanooga: Manufacturers Record, Baltimore, Md., May 12, 1910, pp. 49–54.

$9.68 and the estimates for costs at Chattanooga range from $10.40 to $10.85 per ton. These costs at Chattanooga, it should be noted, are conditioned on large output, regular operation, and good management. The higher costs at Chattanooga are due in large part to the differences in costs of coke at the furnaces in Chattanooga and at Birmingham, and to a lesser degree to the differences in the costs of ores. (The figures quoted are those for the early part of 1910. It is possible that the prices of coke and iron ore may have increased during the last three years.) The cost of conversion of iron into steel should be no greater at Chattanooga than elsewhere, and perhaps less, since steam coal is cheap and labor conditions are excellent.

(4) Manufacturing sites. There are many favorable manufacturing sites at Chattanooga, and an unlimited supply of good water in Tennessee River. (Indeed the prestige that this city has already attained is due in no small degree to the abundance of cheap factory sites and the large amount of pleasantly located land available for workmen's homes.)

(5) Markets. Chattanooga is, properly speaking, the most centrally located city in the South, and enjoys a large and rapidly increasing local demand for structural steel, and steel for general manufacturing purposes, as well as a large and expanding trade territory that will doubtless be greatly increased by the opening of the Panama canal.

(6) Competition. It is considered that in the manufacture of roofing and other light sheets, structural shapes and light rails, Chattanooga would have relatively little competition from other steel plants in the South, including those on the Ohio River in Kentucky.

(7) Transportation facilities. Chattanooga is especially favored in the matter of railways, no less than five systems radiating from the city. The Tennessee River is navigable for eight months in the year from Chattanooga to the Ohio River, and upon the completion of the dam and lock at Hales Bar, below Chattanooga, there will be a sufficient stage of water to make navigation up-stream more practicable than it is at present, and will afford water transportation for coal from mines below the city.

Statistics.

In the following table are given the statistics of production for the last 5 years of the principal minerals mined in Tennessee, viz., coal and iron ore, and the secondary products coke and pig iron. There is also included the production of limestone for flux, so that at a glance there may be ascertained the output and value of the raw materials entering into the producion of pig iron. Roughly, the proportion of tonnage of output of raw ore to pig iron may be deduced. In

PLATE XVII.

INDUSTRIAL CHATTANOOGA.

1911 this ratio was approximately as 100 to 63. This, of course, is a much higher percentage of pig iron than would be yielded by a given quantity of iron ore of the grade that is mined in Tennessee. Considerable brown ore, and a little red ore from Alabama and Georgia, and a little magnetite from North Carolina are reduced to pig iron in Tennessee. Moreover, the production and consumption or iron ore from year to year do not balance, so that the deduction is not very close.

The values given in the table represent, as nearly as can be ascertained, the selling price (not the costs) of the products at the mine, quarry, coke oven, and blast furnace, and should not include any transtation charges. The sharp reduction in the prices of all the commodities at the end of 1907, and the gradual reductions since then in all except limestone are of interest.

PRODUCTION OF IRON ORE, COAL, LIMESTONE, COKE, AND PIG IRON IN TENNESSEE, 1907 TO 1911.

	1907.			1908.			1909.			1910.			1911.			
	Quantity.	Value.	Aver. price per ton	Quantity.	Value.	Aver. price per ton	Quantity.	Value.	Aver. price per ton	Quantity.	Value.	Aver. price per ton	Quantity.	Value.	Aver. price per ton	
Iron ore:																
Red ore	269,182	$ 404,273	$ 1 50	226,038	$286,750	$1 27	298,818	$387,139	$ 1 30	301,838	$ 376,005	$ 1 25	251,083	$ 315,384	$ 1 26	Long tons
Brown ore	544,508	920,861	1 69	409,305	589,257	1 44	358,977	520,143	1 45	430,409	672,318	1 56	218,645	316,955	1 45	Long tons
Limestone for flux	299,247	169,775	57	260,294	142,573	55	157,789	[3]87,432	55	182,561	100,458	55	198,050	[4]109,633	55	Long tons
Coal (bituminous)	6,810,243	8,490,334	1 25	6,199,171	7,118,499	1 15	6,358,645	6,920,564	1 09	7,121,380	7,925,350	1 11	6,433,156	7,209,734	1 12	Short tons
Coke	467,499	1,592,225	3 41	214,528	561,789	2 62	261,808	667,723	2 55	322,756	959,104	2 97	330,418	797,758	2 41	Short tons
Pig iron	[1]393,106	7,542,000	19 19	[1]290,826	4,011,000	13 79	[1]333,845	[2]4,647,000	13 92	400,269	5,199,099	12 99	297,594	3,439,644	11 56	Long tons

[1]Figures of American Iron and Steel Association.
[2]Estimated value applied to American Iron and Steel Association production.
[3]Includes small production from North Carolina.
[4]Includes small production from South Carolina.

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